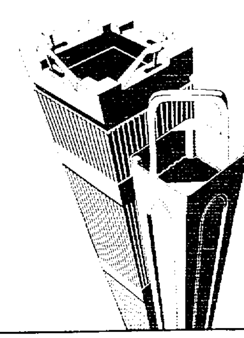
SIEMENS

EMF-2245(NP)(A)
Revision 0

Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel

August 2000



Siemens Power Corporation
Nuclear Division

Siemens Power Corporation

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EMF-2245(NP)
Revision 0

Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel

Prepared: R. B. Macduff, Engineer, Safety Analysis Methods — H. D. Curet, Manager, Product Licensing — 8/10/99 8/4/55 Date

Reviewed: T. H. Keheley, Engineer, Safety Analysis Methods — 10 Aug 99 Date

Concurred: for J. F. Mallay, Director, Regulatory Affairs — 8/10/99 Date

Approved: M. E. Garrett, Manager, BWR Safety Analysis — 8-10-99 Date

Approved: R. E. Collingham, Manager, Safety Analysis Methods — 8/10/99 Date

/arn

U.S. Nuclear Regulatory Commission
Report Disclaimer

Important Notice Regarding the Contents and Use of This Document

Please Read Carefully

This technical report was derived through research and development programs sponsored by Siemens Power Corporation. It is being submitted by Siemens Power Corporation to the U.S. Nuclear Regulatory Commission as part of a technical contribution to facilitate safety analyses by licensees of the U.S. Nuclear Regulatory Commission which utilize Siemens Power Corporation fabricated reload fuel or technical services provided by Siemens Power Corporation for light water power reactors and it is true and correct to the best of Siemens Power Corporation's knowledge, information, and belief. The information contained herein may be used by the U.S. Nuclear Regulatory Commission in its review of this report and, under the terms of the respective agreements, by licensees or applicants before the U.S. Nuclear Regulatory Commission which are customers of Siemens Power Corporation in their demonstration of compliance with the U.S. Nuclear Regulatory Commission's regulations.

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 30, 2000

Mr. James F. Mallay
Director, Nuclear Regulatory Affairs
Siemens Power Corporation
2101 Horn Rapids Road
Richland, WA 99352

SUBJECT: ACCEPTANCE FOR REFERENCING OF SIEMENS POWER CORPORATION TOPICAL REPORT EMF-2245(P), REVISION 0, "APPLICATION OF SIEMENS POWER CORPORATION'S CRITICAL POWER CORRELATIONS TO CO-RESIDENT FUEL" (TAC NO. MA6438)

Dear Mr. Mallay:

The subject topical report was submitted by Siemens Power Corporation (SPC) by letter dated August 11, 1999. This topical report presents two processes for the application of an approved SPC critical power correlation to pre-existing co-resident fuel, when an SPC fuel design is introduced into a reload core. One process is a generic extension of a previously approved SPC methodology. The second process describes a new method to use an approved SPC critical power correlation to directly evaluate available experimental heat transfer data specific to the co-resident fuel to determine a specific set of critical power correlation additive constants for the co-resident fuel. These processes may be used by SPC and/or licensees (under Generic Letter 83-11, Supplement 1, "Guidelines for Qualifying Licensees to Use Generically Approved Analysis Methods" guidelines) to conservatively apply approved SPC critical power correlations to co-resident fuel from prior reloads.

The staff has reviewed the topical report and finds it acceptable for referencing in licensing actions as stated in the enclosed safety evaluation (SE).

Pursuant to 10 CFR 2.790, we have determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for a period of ten (10) working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.790.

The staff will not repeat its review and acceptance of the matters described in the report, when the report appears as a reference in license applications, except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with the procedures established in NUREG-0390, the NRC requests that SPC publish accepted versions of the report, including the safety evaluation, in the proprietary and non-proprietary forms within 3 months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted versions shall include a "-A" (designating accepted) following the report identification symbol. The accepted versions shall also incorporate all communications between SPC and the staff during this review.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are no longer valid, SPC and the licensees referencing the topical report will be expected to revise and resubmit their respective documentation, or to submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

Michael T. Masnik for

Stuart A. Richards, Director
Project Directorate IV and Decommissioning
Division of Licensing Project management
Office of Nuclear Reactor Regulation

Project No. 702

Enclosure: Safety Evaluation

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT EMF-2245(P), REVISION 0,

"APPLICATION OF SIEMENS POWER CORPORATION'S CRITICAL POWER CORRELATIONS TO CO-RESIDENT FUEL"

SIEMENS POWER CORPORATION

PROJECT NO. 702

1.0 BACKGROUND

By letter of August 11, 1999 (Reference 1), Siemens Power Corporation (SPC) requested NRC review of EMF-2245(P) Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel." All recent SPC critical power correlations (e.g., ANFB, SPCB series) use a basic functional relationship between boiling transition and nominal fuel bundle operating conditions of coolant inlet mass flow rate, pressure and inlet enthalpy. This is accomplished by determining correlation coefficients fit to measured critical heat flux data, with specific additive constants used to account for specific fuel design features. In this approach, local effects due to such factors as flow channel geometry, radial power distribution, axial power distribution, and grid spacer design use a prescribed formula, correlated by means of a local energy balance term and a set of empirical additive constants on this term.

When boiling water reactor (BWR) reload fuel supplied by SPC is loaded into a reactor core, the critical power performance of both the co-resident fuel (remaining from prior reloads) and the new SPC reload fuel must be evaluated on a consistent and conservative basis. The fuel rod and bundle configuration for the SPC reload fuel and the prior co-resident fuel may physically differ in fuel lattice design (e.g., 9x9 versus 10x10 rod array), and bundle design (grid spacer design, part length rods, etc.). In such cases, measured critical power data for the specific co-resident fuel design parameters may not be contained in the SPC critical power correlation verification and validation data base. Therefore, a consistent methodology for evaluating the critical power performance of each different fuel design must ensure that the use of a specific SPC critical power correlation will conservatively determine the performance of the co-resident fuel design. SPC proposes to accomplish this either by an indirect or a direct evaluation process.

Topical Report EMF-2245(P) describes the processes for the application of approved SPC BWR critical power correlations to the co-resident fuel remaining from prior reloads. One process is a generic extension of a previously approved co-resident methodology (Reference 2). The other process describes the use of an approved SPC critical power correlation to directly evaluate experimental heat transfer data, specific to the co-resident fuel, to determine the appropriate set of additive constants for the co-resident fuel.

The indirect process is used when co-resident fuel critical power correlation coefficients (and uncertainty) is available to SPC and/or the licensee, but the underlying experimental critical power data for the co-resident fuel design is not available. The direct process is used when sufficient experimental critical power data for the co-resident fuel design is available to SPC and/or the licensee.

The two processes described in this topical report are intended for application only for previously exposed co-resident fuel to confirm that sufficient margin to the safety limit exists for both the co-resident fuel and the SPC fuel. These processes and analyses are not applicable (nor required) for support of lead test assembly evaluations.

2.0 EVALUATION

The SPC BWR critical power correlations are designed for application to steady-state and transient critical heat flux (CHF) safety evaluations for SPC BWR fuel designs. The SPC correlations are developed to predict the limiting fuel rod in a bundle and to account for specific fuel design bundle geometry and local spacer effects on the critical power by deriving a set of constants, typically referred to as "Additive Constants," one constant for each rod in the bundle. Each individual fuel bundle design requires a unique set of additive constants.

The SPC critical power correlations are empirically derived expressions with coefficients that are a function of the operating parameters: local coolant enthalpy, coolant mass flow, and pressure. The input operating parameters span the range of pressure, mass velocity, and inlet subcooling covering the expected operating and accident conditions. The correlation coefficients are based on local coolant conditions predicted from both uniform and non-uniform axial power distribution test data. The correlations include correction factors to account for specific geometry and non-uniform axial power distributions that deviate from the correlation test data conditions.

The low-flow and high-flow behavior of the correlation are captured by refining the parameters in the correlation equations. These parameters address the impact of variations in the local enthalpy from the planar average enthalpy. One of these parameters characterizes fuel rod local behavior, such as enthalpy rise, and also factors additive constants into the correlation. The additive constants account for the fuel bundle geometry and spacer effects on the critical power behavior of the bundle.

2.1 Indirect Correlation Application

The indirect correlation application (ICA) process is used when either no experimental critical heat transfer data are available to SPC or to the licensee for the co-resident fuel or when insufficient data are available for the range of conditions for which the SPC correlation is to be applied. This process involves generically expanding the application of a previously approved co-resident methodology, which was used for the approved ANFB correlation (Reference 3), to allow using other approved SPC critical power correlations which use additive constants.

The ICA process is applied to previously exposed co-resident fuel by:

1. Determining additive constants for co-resident fuel with insufficient or no experimental data in the SPC or licensee data base for the specific SPC critical power correlation to be used, but for which a calculated critical power data base (with uncertainties) from another approved correlation is available,

2. Performing a rigorous statistical evaluation of the approved critical power correlation for the co-resident fuel design to determine its standard deviation for the predicted critical power ratio data base, and

3. Using appropriate co-variance, calculate a combined standard deviation as the product of two random variables: (a) the ratio of the SPC correlation standard deviation to the approved co-resident fuel design standard deviation, and (b) the co-resident fuel correlation standard deviation.

The additive constant uncertainty for the co-resident fuel to be applied by the SPC critical power correlation [for use in the approved SPC safety limit methodology (Reference 4)] is determined from the above combined standard deviation, conservatively adjusted by the specific SPC critical power correlation uncertainty standard deviation, and the additive constant uncertainty standard deviation for the data obtained for all designs tested and included in the correlation data base.

2.2 Direct Correlation Application

The direct correlation application process is used to determine the additive constants and the additive constant uncertainties for an experimentally tested co-resident fuel design, based on sufficient experimental critical power data, which is available to the licensee and/or SPC. This process uses an approved SPC critical power correlation with approved procedures to directly evaluate the experimental critical heat transfer data specific to the co-resident fuel in order to determine the set of additive constants for the co-resident fuel and to determine the behavior of the SPC correlation over the range of conditions used to obtain the data.

This process is applied to previously exposed co-resident fuel by:

1. Determining the additive constants for co-resident fuel when sufficient experimental critical heat transfer data for the co-resident fuel is available to SPC and/or the licensee, but which data have not yet been evaluated with a specific approved SPC critical power correlation,

2. Performing a rigorous statistical evaluation of the approved SPC critical power correlation used for the co-resident fuel design to determine the standard deviation of the correlation from the experimental critical power ratio data and of the additive constants within the evaluated data base,

3. Evaluating the application process for the co-resident fuel critical power correlation to determine that no unexpected trends are observed, and

4. Ensuring that the co-resident critical power experimental data ranges are adequate for the intended evaluations and are comparable to those used to develop the SPC critical power correlation.

This process uses approved SPC processes and procedures to evaluate the co-resident fuel experimental critical power data. Since the data is normally proprietary to the co-resident fuel vendor, the licensee is responsible for determining the additive constants and uncertainties using the approved SPC procedures. As discussed below, the licensee must be qualified to perform this process.

2.3 Technology Transfer Requirement

Licensees may be responsible for and participate in the analyses required for either the indirect or the direct correlation process. Therefore, it is necessary that these licensees fully understand the process, methodology and procedures used, and are capable of independently performing or reviewing the evaluations. SPC has described their technology transfer program (Reference 5), which the licensees must successfully complete in order to perform their own thermal-hydraulic calculations using the SPC SPCB correlation and the SPC XCOBRA-T transient code (Reference 6) in support of reload analyses. The overall process consists of training, benchmarking, and change control. In addition, SPC described the process for a licensee to implement a new correlation (e.g., SPCB). This process includes performance of an independent benchmarking calculation by SPC for comparison to the licensee-generated results to verify that the critical power (CP) correlation is properly applied.

Generic Letter (GL) 83-11, Supplement 1 (Reference 7) provides guidelines for qualifying licensees to use NRC-approved analysis methods. The lead licensee for application of this topical report has committed to implement these guidelines for safety analyses using SPC methodology to apply approved SPC critical power correlations to co-resident fuel (Reference 8). The staff has reviewed the SPC process and licensee commitments and finds this acceptable since training, bench-marking and change control have been adequately addressed, as required by GL 83-11, Supplement 1.

2.4 Summary

The two processes described in this topical report are based on approved SPC methodologies and procedures. Therefore, their application by SPC to previously exposed co-resident fuel in safety analyses for mixed reload cores is acceptable to the staff. Participation by the licensee in the safety analyses is controlled by the stipulation that licensee involvement be performed in accordance with the guidelines of GL 83-11, Supplement 1. This ensures that adequate licensee training, code benchmarking and change control are maintained. This is acceptable to the staff.

3.0 CONCLUSION

The staff has reviewed the processes and evaluations described in Topical Report EMF-2245(P), Revision 0, "Application of Siemens Power Corporations's Critical Power Correlations to Co-Resident Fuel." The staff also reviewed the limitations imposed on licensee application of SPC CP correlations, as discussed in the staff's SE for Topical Report EMF-2209(P)

(Reference 9) for the latest approved SPC CP correlation (SPCB). The staff also reviewed the lead licensee's commitment to apply GL 83-11 Supplement 1 guidelines with the topical report and concludes that, as discussed above, Topical Report EMF-2245(P) is acceptable for referencing in licensing applications, subject to the following condition:

> Technology transfer to licensees who may be responsible for using these processes will be accomplished through SPC and licensee procedures consistent with the requirements of GL 83-11, Supplement 1. This process includes the performance of an independent bench-marking calculation by SPC for comparison to licensee-generated results to verify that the application of SPC CHF correlations is properly applied for the first application by a licensee.

4.0 REFERENCES

1. Letter from J. F. Mallay (SPC) to U. S. NRC, "Request for Review of EMF-2245(P) Revision 0, 'Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel,'" NRC:99:034, August, 11, 1999.

2. EMF-1125(P)(A), Supplement 1, Appendix C, "ANFB Critical Power Correlation Application for Co-Resident Fuel," Siemens Power Corporation, August 1997.

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

4. ANF-524(P)(A), Revision 2 and Supplements 1 and 2, "ANF Critical Power Methodology for Boiling Water Reactors," Advanced Nuclear Fuels, November 1990.

5. Letter from J. F. Mallay (SPC) to the U.S. Nuclear Regulatory Commission, "SER Conditions for EMF-2209(P) Revision 1, SPCB Critical Power Correlation," April 24, 2000.

6. XN-NF-84-105(P)(A), "XCOBRA-T: A Computer Code for BWR Transient Thermal-Hydraulic Core Analysis," Exxon Nuclear Company, Richland, WA 99352, February 1987.

7. Generic Letter 83-11, Supplement 1, "Guidelines for Qualifying Licensees to Use Generically Approved Analysis Methods," June 24, 1999.

8. Letter from M. A. Krupa (EOI) to U.S. NRC, "Implementation of GL 83-11, Supplement 1, for Co-Resident Fuel CPR Calculations," August 4, 2000.

9. Letter from U.S. NRC to J. F. Mallay (SPC), "Acceptance for Referencing of Licensing Topical EMF-2209(P), Revision 1, 'SPCB Critical Power Correlation'", July 3, 2000.

Principal Contributor: E. Kendrick

Date: August 30, 2000

SIEMENS

August 11, 1999
NRC:99:034

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Review of EMF-2245(P) Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel"

Ref.: 1. EMF-1125(P)(A) Supplement 1 Appendix C, "ANFB Critical Power Correlation Application for Co-Resident Fuel," Siemens Power Corporation, August 1997.

Ref.: 2. Letter, James E. Lyons (NRC) to R. A. Copeland (SPC), "Acceptance for Referencing of Licensing Topical Report EMF-1125, Supplement 1 Appendix C, 'ANFB Critical Power Correlation Application for Co-Resident Fuel,'" May 9, 1997.

Enclosed are 15 copies of the proprietary and 12 copies of the nonproprietary version of EMF-2245(P) Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel." (NOTE: Three proprietary copies and one nonproprietary copy have been forwarded to Mr. Stephen Dembek). The topical report presents two processes for the application of approved SPC correlations to co-resident fuel – one process is an extension of the methodology presented in Reference 1 and approved by Reference 2 and the other process uses an approved SPC critical power correlation to directly evaluate experimental heat transfer data specific to the co-resident fuel to determine the set of additive constants for the co-resident fuel.

Some of the information contained in the enclosed topical report is considered to be proprietary to Siemens Power Corporation. As required by 10 CFR 2.790(b), an affidavit is enclosed to support the withholding of this information from public disclosure.

Very truly yours,

James F. Mallay, Director
Regulatory Affairs

/arn
Enclosures

cc: Mr. S. Dembek (3 proprietary/1 nonproprietary)
Mr. J. L. Wermiel
Project No. 702 (12 proprietary/11 nonproprietary)

Siemens Power Corporation

2101 Horn Rapids Road
Richland, WA 99352

Tel: (509) 375-8100
Fax: (509) 375-8402

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

I, H. Donald Curet, being duly sworn, hereby say and depose:

1. I am Manager, Product Licensing, for Siemens Power Corporation ("SPC"), and as such I am authorized to execute this Affidavit.

2. I am familiar with SPC's detailed document control system and policies which govern the protection and control of information.

3. I am familiar with the SPC information included in report EMF-2245(P) Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel," August 1999 referred to as "Document" transmitted by letter NRC:99:034. Information contained in this Document has been classified by SPC as proprietary in accordance with the control system and policies established by SPC for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by SPC and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence, with the request that the information contained in the Document will not be disclosed or divulged.

6. This Document contains information which is vital to a competitive advantage of SPC and would be helpful to competitors of SPC when competing with SPC.

7. The information contained in this Document is considered to be proprietary by SPC because it reveals certain distinguishing aspects of SPC licensing methodology which secure competitive advantage to SPC for fuel design optimization and marketability, and includes information utilized by SPC in its business which affords SPC an opportunity to obtain a competitive advantage over its competitors who do not or may not know or use the information contained in this Document.

8. The disclosure of the proprietary information contained in this Document to a competitor would permit the competitor to reduce its expenditure of money and manpower and to improve its competitive position by giving it valuable insights into SPC licensing methodology and would result in substantial harm to the competitive position of SPC.

9. This Document contains proprietary information which is held in confidence by SPC and is not available in public sources.

10. In accordance with SPC's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside SPC only as required and under suitable agreement providing for nondisclosure and limited use of the information.

11. SPC policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

12. Information in this Document provides insight into licensing methodology developed by SPC. SPC has invested significant resources in developing the methodology as well as the strategy for this application.

Assuming a competitor had available the same background data and incentives as SPC, the competitor might, at a minimum, develop the information for the same expenditure of manpower and money as SPC.

13. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 11th

day of August, 1999.

Sue M. Galpin
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 02/27/00

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

October 1, 1999

Mr. James F. Mallay
Director, Regulatory Affairs
Siemens Power Corporation
2101 Horn Rapids Road
Richland, WA 99352

SUBJECT: REVIEW OF TOPICAL REPORT EMF-2245(P) REVISION 0, "APPLICATION OF SIEMENS POWER CORPORATION'S CRITICAL POWER CORRELATIONS TO CO-RESIDENT FUEL," PROJECT NO. 702 (TAC NO. MA6438)

Dear Mr. Mallay:

By your letter dated August 11, 1999, and affidavit dated August 11, 1999, executed by H. Donald Cruet, you submitted Topical Report EMF-2245(P), Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel."

You had stated some of the information contained in the topical report is considered to be proprietary to Siemens Power Corporation (SPC) and requested that it be withheld from public disclosure pursuant to 10 CFR 2.790. A nonproprietary version was submitted for placement in the NRC public document room.

The affidavit stated that the submitted information should be considered exempt from mandatory public disclosure for the following reasons:

"6. This Document contains information which is vital to a competitive advantage of SPC and would be helpful to competitors of SPC when competing with SPC.

7. The information contained in this Document is considered to be proprietary by SPC because it reveals certain distinguishing aspects of SPC licensing methodology which secure competitive advantage to SPC for fuel design optimization and marketability, and includes information utilized by SPC in its business which affords SPC an opportunity to obtain a competitive advantage over its competitors who do not or may not know or use the information contained in the Document.

8. The disclosure of the proprietary information contained in this Document to a competitor would permit the competitor to reduce its expenditure of money and manpower and to improve its competitive position by giving it valuable insights into SPC licensing methodology and would result in substantial harm to the competitive position of SPC.

9. The Document contains proprietary information which is held in confidence by SPC and is not available in public sources.

10. In accordance with SPC's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside SPC only as required and under suitable agreement providing for nondisclosure and limited use of the information.

11. SPC policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

12. Information in this Document provides insight into licensing methodology developed by SPC. SPC has invested significant resources in developing the methodology as well as the strategy for this application. Assuming a competitor had available the same background data and incentives as SPC, the competitor might, at a minimum, develop the information for the same expenditure of manpower and money as SPC."

We have reviewed your application and the material in accordance with the requirements of 10 CFR 2.790 and, on the basis of your statements, have determined that the submitted information sought to be withheld contains proprietary commercial information and should be withheld from public disclosure.

Therefore, the version of Topical Report EMF-2245(P), Revision 0, "Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel," marked as proprietary will be withheld from public disclosure pursuant to 10 CFR 2.790(b)(5) and Section 103(b) of the Atomic Energy Act of 1954, as amended.

Withholding from public inspection shall not affect the right, if any, of persons properly and directly concerned to inspect the documents. If the need arises, we may send copies of this information to our consultants working in this area. We will, of course, ensure that the consultants have signed the appropriate agreements for handling proprietary information.

If the basis for withholding this information from public inspection should change in the future such that the information could then be made available for public inspection, you should promptly notify the NRC. You also should understand that the NRC may have cause to review this determination in the future, for example, if the scope of a Freedom of Information Act request includes your information. In all review situations, if the NRC makes a determination adverse to the above, you will be notified in advance of any public disclosure.

If you have any questions regarding this matter, I may be reached at 301-415-1480.

Sincerely,

Nageswaran Kalyanam, Project Manager, Section 2
Project Directorate IV & Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 702

EMF-2245(NP)
Revision 0

Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel

August 1999

Nature of Changes

Item	Paragraph or Page(s)	Description and Justification
1.	All	This is a new document.

Contents

Tables

1.0 Abstract

When BWR fuel supplied by Siemens Power Corporation (SPC) is initially loaded into a reactor, the critical power performance of both the remaining co-resident fuel and the SPC fuel must be evaluated. This topical report presents two processes for the application of an approved SPC critical power correlation to co-resident fuel.

- One process (Indirect Correlation Application) is implemented when either no experimental critical heat transfer data are available to SPC or the licensee for the co-resident fuel or when insufficient data are available for the range of conditions for which the SPC correlation is to be applied. This process involves the generic application of the approved methodology in Reference 1 using any approved SPC critical power correlation which uses additive constants.
- The second process (Direct Correlation Application) is used to determine the additive constants and additive constant uncertainties for a tested, co-resident fuel design based on experimental critical power data. This process uses an approved SPC critical power correlation to directly evaluate experimental critical heat transfer data specific to the co-resident fuel to determine the set of additive constants for the co-resident fuel and to determine the behavior of the correlation over the range of conditions used to obtain the data.

The processes described in this topical report will only be applied to previously exposed co-resident fuel. These processes are used to confirm that sufficient margin exists to the safety limit for both the co-resident fuel and the SPC fuel. (Note: Analyses to support lead test assemblies are exempt from the processes.)

2.0 Introduction and Summary

When SPC BWR fuel is initially loaded into a reactor the critical power performance as well as the associated uncertainties of both the remaining co-resident fuel and the SPC fuel are required to perform core safety analyses. The designs for the SPC fuel and co-resident fuel may differ (e.g., 9x9 with 10x10, with and without part length fuel rods) and the critical power data for the co-resident fuel may not be contained in the SPC critical power correlation data base. Therefore, a methodology for evaluating the critical power performance of both fuel designs must accommodate the use of an SPC specific critical power correlation to conservatively determine the critical power performance of the co-resident fuel. This evaluation can be accomplished by either an indirect or direct evaluation process. The indirect process is used when the co-resident fuel critical power correlation is available but the experimental critical power data for the co-resident fuel is not. The direct process is used when the experimental critical power data for the co-resident fuel are available. This topical report presents two processes for the application of an approved SPC critical power correlation to a co-resident fuel design. They are:

<u>Indirect Correlation Application</u>

The indirect process for the application of approved SPC critical power correlations to various co-resident fuel designs is discussed in Section 3.1. This process is based upon a broader application of the methodology described in Reference 1 which was specifically approved for the application of the ANFB critical power correlation (Reference 2) to co-resident fuel. This process involves the application of any approved critical power correlation (e.g., References 2 and 3) or future approved SPC critical power correlation which uses additive constants and the approved methodology (Reference 1). The process will only be applied to previously exposed co-resident fuel. The process involves the following steps:

- determination of additive constants for co-resident fuel that has no data in the data base for the specific SPC critical power correlation used, but for which a calculated critical power data base from another approved correlation is available,
- performing a statistical evaluation of the critical power correlation approved for the co-resident fuel type to determine its standard deviation for the predicted critical power ratio data base, and

- using co-variance, calculate a combined standard deviation as the product of two random variables with the variables being the SPC correlation standard deviation to the co-resident fuel correlation standard deviation and the co-resident fuel correlation standard deviation.

The equation used to determine the combined standard deviation is discussed in Section 3 and is of the following formulation:

The additive constant uncertainty to be applied by the SPC critical power correlation to the co-resident fuel for use in the approved safety limit methodology (Reference 4) is determined by dividing the combined standard deviation by the factor F:

The value of F is determined from the specific SPC critical power correlation uncertainty standard deviation and the additive constant uncertainty standard deviation for data obtained for all designs tested and included in the correlation data base. The determination of the additive constant uncertainty for the co-resident fuel is discussed in Section 3.

Direct Correlation Application

The direct process for the application of approved SPC critical power correlations to various co-resident fuel designs is discussed in Section 3.2. Though not necessary, as in the case of the indirect process, this direct process shall only be applied to previously exposed co-resident fuel. The process involves the following steps:

- determining additive constants for co-resident fuel when experimental critical heat transfer data for the co-resident fuel are available but have not yet been evaluated using a specific SPC critical power correlation,
- performing a statistical evaluation of the critical power correlation approved for the co-resident fuel type to determine the standard deviation of the correlation from the experimental critical power ratio (ECPR) data and of the additive constants within the data base evaluated,
- evaluating the application process for the co-resident fuel critical power correlation to determine that no unexpected trends are observed, and
- ensuring that co-resident critical power data range is adequate and comparable to that used to develop the SPC critical power correlation.

3.0 Critical Power Ratio Correlation Application Process

This section provides descriptions of the indirect and direct critical power ratio (CPR) correlation application processes that may be used for evaluating the critical power performance of co-resident fuel. Both processes are based upon and the use of previously approved correlations and methodologies. The purpose of this topical report is to describe extended applications of the approved processes.

3.1 *Indirect Correlation Application*

NRC-approved critical power correlations developed by SPC are based upon experimental data for each of the different SPC fuel designs in its data base. For those instances where a reload of SPC fuel is introduced into a core with co-resident fuel which is not part of the existing SPC data base, a process is needed to demonstrate the safety of this core configuration. Specifically, the additive constants and additive constant uncertainties for the co-resident fuel must be consistent with the requirements of the specific critical power correlation to be used. Such a process was approved for the use of the ANFB critical power correlation (Reference 1).

This process, which is statistical in nature, is generically applicable to any SPC critical power correlation approved by the NRC that is formulated to use additive constants and uses an approved procedure to determine additive constants and additive constant uncertainties.

Examples of tabulated results for use in the above equations are provided in Table 3.1. Using these tabulated values produces a value for [ ] the calculated value for the additive constant uncertainty for the co-resident fuel safety limit calculations would be [ ] This value of [ ] compares to an additive constant uncertainty value of [ ] normally calculated for fuel designs tested and within the SPC critical power data base. Thus, this process increases the additive constant uncertainty (standard deviation) so that the limits used for the co-resident fuel will be more restrictive than the limits that would be derived from a direct comparison of the correlation to the data. The larger combined standard deviation results in an increase in the fraction of rods calculated in boiling transition for a given safety limit and may increase the safety limit.

3.2 *Direct Correlation Application*

The direct correlation application process may be used when critical power correlation data are available for the co-resident fuel. When such data are available, the process uses an SPC-approved critical power correlation and the approved procedures to determine additive constants and additive constant uncertainties to:

- determine additive constants for the co-resident fuel from the experimental critical heat transfer data for the co-resident fuel using a specific SPC critical power correlation,
- perform a statistical characterization of the SPC critical power correlation selected to model the co-resident fuel type to determine the standard deviation of the correlation from the co-resident ECPR data and of the additive constants within the data base evaluated, and
- evaluate the application process for the co-resident fuel critical power correlation to determine that no unexpected trends are observed.

This process is simply an application of approved procedures used by SPC to determine additive constants and additive constant uncertainties from experimental critical power data for co-resident fuel in a manner identical to those followed if the data were SPC data. The only difference is that the co-resident critical power data are anticipated to be proprietary to the vendor of the co-resident fuel and the owner of the fuel will have to determine the additive constants and additive constant uncertainties using approved SPC procedures and processes.

Table 3.1 Example of Results Used to Determine σ_{Total}

4.0 Results of Safety Analyses

This section provides a discussion of the possible effect of the indirect and direct CPR correlation application processes described in this report on calculated MCPR safety limit.

4.1 *Indirect Correlation Application*

The potential effect of an increase in the standard deviation of the additive constant has been assessed in Reference 1, where SPC performed an MCPR safety limit sensitivity analysis. In SPC's approved safety limit methodology (Reference 4) the power of the limiting assembly is raised until this assembly is at the critical power safety limit. Then Monte Carlo calculations are performed to assess the impact of the uncertainties of various plant and analyses parameters, including those for additive constants. The Monte Carlo calculations establish the MCPR safety limit at which 99.9% of the rods are not in boiling transition, including uncertainties.

The sensitivity analysis was performed using a previous MCPR safety limit analysis. The additive constant uncertainty was increased by [ ] for all fuel types in the core. The results of the sensitivity analysis indicate that for an additive constant uncertainty increase of [ ] the MCPR safety limit would increase by about [ ] to protect 99.9% of the fuel rods in the core from boiling transition. The analysis demonstrated that significant conservatism is introduced for the co-resident fuel by using the additive constant uncertainty generation process described in Section 3.1.

The indirect process described in Section 3.1 for determining additive constants and uncertainties for co-resident fuel will be applied only to fuel with at least one cycle of exposure. Because the MCPR safety limit is primarily controlled by first cycle fuel, (the end of cycle conditions are normally limiting for MCPR safety limit), the effect of using this process for additive constants will be less than that obtained from the sensitivity study and in many cases will not result in any increase in the safety limit.

Both the MCPR safety limit and the transient CPR response are most limiting near end of cycle (EOC). Because the MCPR operating limit for the entire cycle is based on EOC conditions, significant margin exists to the safety limit for both SPC and co-resident fuel during transients early in the cycle. Over most of the cycle, and certainly at EOC conditions where minimum margin to the safety limit occurs, the co-resident fuel will have more margin to its MCPR operating limit than the SPC fuel. At EOC conditions, the co-resident 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. The inherent MCPR margin of the co-resident fuel combined with the conservative method of developing additive constant uncertainties ensures that the co-resident fuel will be non-limiting relative to the SPC fuel (i.e., co-resident fuel will have more margin to boiling transition during potential transients).

4.2 *Direct Correlation Application*

The direct process described in Section 3.2 for determining additive constants and uncertainties for co-resident fuel will also be applied only to fuel with at least one cycle of exposure. The effect of the additive constant uncertainty determined by the direct process on the calculated MCPR safety limit would be expected to be less than that determined from the indirect process. This is primarily because the uncertainty is determined directly from data and will be less than the uncertainty calculated from the indirect process which includes the co-variance of the uncertainties of both data and critical power correlation. Also, as with the indirect process, the MCPR safety limit is primarily controlled by first cycle fuel (the end of cycle conditions are normally limiting for the MCPR safety limit).

5.0 References

1. EMF-1125(P)(A) Supplement 1, Appendix C, "ANFB Critical Power Correlation Application for Co-Resident Fuel," Siemens Power Corporation, August 1997.

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

3. EMF-1997(P)(A) Revision 0, "ANFB-10 Critical Power Correlation," Siemens Power Corporation, July 1998.

4. ANF-524(P)(A) Revision 2 and Supplements 1 and 2, "ANF Critical Power Methodology for Boiling Water Reactors," Advanced Nuclear Fuels, November 1990.

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