SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors

EMF-2310, Revision 1
Supplement 2NP-A,
Revision 0

Topical Report

March 2023

FRAMATOME TRADEMARKS

GAIA, HMP, and HTP are trademarks or registered trademarks of Framatome or its affiliates, in the USA or other countries.

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

February 9, 2023

Ms. Gayle Elliott, Director
Licensing and Regulatory Affairs
Framatome, Inc.
3315 Old Forest Road
Lynchburg, VA 24501

SUBJECT: FINAL SAFETY EVALUATION FOR FRAMATOME TOPICAL REPORT EMF-2310, REVISION 1 SUPPLEMENT 2P, REVISION 0, "SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED WATER REACTORS" (EPID L-2022-TOP-0008)

Dear Ms. Elliott:

By letter dated February 24, 2022 (Agencywide Documents Access and Management System Package Accession No. ML22060A164), as supplemented by letter dated August 31, 2022 (ADAMS Accession No. ML22245A097), Framatome, Inc. (Framatome) submitted Topical Report (TR) EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," for U.S. Nuclear Regulatory Commission (NRC) staff review. By e-mail letter dated April 11, 2022 (ADAMS Accession No. ML22098A184), the NRC staff accepted the TR for review.

By e-mail dated November 30, 2022 (ADAMS Accession No. ML22298A073), an NRC draft safety evaluation (SE) regarding approval of EMF-2310, Revision 1, Supplement 2P, Revision 0, was provided to Framatome for proprietary review. By letter dated January 5, 2023 (ADAMS Accession No. ML23010A042), Framatome provided proprietary markings and comments on the draft SE. The NRC staff's disposition of the Framatome comments on the draft SE are discussed in the attachment of the final SE which is enclosed with this letter.

The NRC staff has found that TR EMF-2310, Revision 1, Supplement 2P, Revision 0, is acceptable for referencing in licensing applications for nuclear power plants to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for the NRC staff's acceptance of the TR.

NOTICE: The enclosure to this letter contains Proprietary Information. When this letter is separated from the enclosure, this letter is decontrolled.

The NRC staff's acceptance applies only to material provided in the subject TR. The NRC staff does not intend to repeat its review of the acceptable material described in the TR. When the TR appears as a reference in licensing applications, the NRC staff's review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant specific review in accordance with applicable NRC review standards.

In accordance with the guidance provided on the NRC website, we request that Framatome publish approved proprietary and non-proprietary versions of TR EMF-2310, Revision 1, Supplement 2P, Revision 0, within three months of receipt of this letter. The approved versions shall incorporate this letter and the enclosed final SE after the title page. For non-proprietary versions, Framatome shall strike the proprietary information markings in this letter and make the appropriate redactions and adjustments to document security classifications to the enclosed SE. Also, they must contain historical review information, including the NRC staff requests for additional information (RAI) and Framatome's responses. The approved versions shall include a "-A" (designating approved) following the TR identification symbol.

As an alternative to including the RAI questions and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAI questions:

1. The RAI questions and RAI responses can be included as an Appendix to the accepted version.

2. The RAI questions and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAI questions and RAI responses which resulted in any changes as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Framatome will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

/RA/

Cindy E. Rosales-Cooper, Acting Chief
Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 99902041
Project No. 728

Enclosure:
Final SE (Proprietary)

SUBJECT: FINAL SAFETY EVALUATION FOR FRAMATOME TOPICAL REPORT EMF-2310, REVISION 1 SUPPLEMENT 2P, REVISION 0, “SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED WATER REACTORS” (EPID L-2022-TOP-0008) DATED: FEBRUARY 9, 2023

DISTRIBUTION:
PUBLIC (Letter)
NON-PUBLIC (Final SE)
RidsNrrOd Resource
RidsNrrDss Resource
RidsNrrLADHarrison Resource
RidsNrrDorl Resource
RidsNrrDorlLlpb Resource
RidsOgcMailCenter Resource
RidsACRS_MailCTR Resource
SKrepel, NRR
JKaizer, NRR
NOtto, NRR
CRosales-Cooper, NSIR

ADAMS Accession Nos.:
ML23023A189 (Package)
ML23023A116 (Letter)
ML23023A139 (Final SE) ***concurrence via email**

OFFICE	NRR/DORL/LLPB/PM*	NRR/DORL/LLPB/LA*	NRR/DSS/SNPB/BC*	OGC – NLO
NAME	NOtto	DHarrison	SKrepel	STurk
DATE	1/18/2023	1/30/2023	1/31/2023	2/8/2023
OFFICE	NRR/DORL/LLPB/BC (A)*			
NAME	CRosales-Cooper			
DATE	2/9/2023			

OFFICIAL RECORD COPY

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT EMF-2310, REVISION 1 SUPPLEMENT 2P, REVISION 0

"SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR PRESSURIZED

WATER REACTORS"

FRAMATOME INC

PROJECT NO 710 DOCKET NO 99902042

EPID NO. L-2022-TOP-0008

1. INTRODUCTION

By letter dated February 24, 2022 (Ref. 1), as supplemented by letter dated August 31, 2022 (Ref. 10), Framatome Inc. (Framatome) submitted Topical Report (TR) EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA [loss-of-coolant accident] Methodology for Pressurized Water Reactors" (Ref. 2) to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. The purpose of the TR is to describe the design limit for the Biasi critical heat flux (CHF) correlation that is used for predicting the CHF performance of the High Thermal Performance (HTP) and High Mechanical Performance (HMP) grids under certain conditions.

The complete list of correspondence between the NRC staff and Framatome is provided in Table 1 below. This includes Requests for Additional Information (RAIs), responses to RAIs, and any other correspondence relevant to this review.

Table 1: List of Key Correspondence

Sender	Document	Document Date	ADAMS Accession No.	Reference
Framatome	Submittal Letter	February 24, 2022	ML22060A118	1
Framatome	Topical Report	February 24, 2022	ML22060A164	2
NRC	Acceptance Letter	April 11, 2022	ML22098A182	7
NRC	RAI – Round 1	July 1, 2022	ML22174A354	9
Framatome	RAI Response – Round 1	August 31, 2022	ML22245A102	10

In performing this review, the NRC staff applied a credibility assessment framework which focused on critical boiling transition[1] models. The framework is fully described throughout this safety evaluation (SE).

[1] Critical boiling transition is the name given to the phenomena which occur when a flow regime that has a higher heat transfer rate transitions to a flow regime that has a significantly lower heat transfer rate. Historically, terms such as critical heat flux, departure from nucleate boiling, and critical power have been used. However, the NRC staff needed a way to separate the general phenomena occurring (i.e., critical boiling transition) from specific types of phenomena which may occur (e.g., departure from nucleate boiling, dryout) and from the specific values of certain parameters which are often used to signify that such a transition has occurred (e.g., critical heat flux, critical power).

2. REGULATORY EVALUATION

Criterion 10, “Reactor Design,” of Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants,” introduces the concept of specified acceptable fuel design limits (SAFDLs). In essence, SAFDLs are those limits placed on certain variables to ensure that the fuel does not fail. One such SAFDL is associated with critical boiling transition (CBT). CBT is defined as a transition from a boiling flow regime that has a higher heat transfer rate to a flow regime that has a significantly lower heat transfer rate. If the reduction in the heat transfer rate and resulting increase in surface temperature is large enough, the surface may weaken or melt. In a nuclear power plant, a CBT on the fuel rod cladding surface could result in fuel damage.

To ensure that such a CBT does not occur, two SAFDLs have been developed, as described in Standard Review Plan (SRP), Section 4.4, “Thermal and Hydraulic Design” (Ref. 3):

(a) *there should be a 95-percent probability at the 95-percent confidence level that the hot rod in the core does not experience a Departure from nucleate boiling (DNB) or boiling crisis condition during normal operation or anticipated operational occurrences (AOOs), or*

(b) *at least 99.9 percent of the fuel rods in the core will not experience a DNB or boiling crisis during normal operation or AOOs.*

Typically, SAFDL (a) is associated with pressurized water reactors (PWRs) and SAFDL (b) is associated with boiling water reactors (BWRs). CBT models such as the Biasi CHF model which will be used on PWR fuel are necessary to ensure that the above SAFDLs can be satisfied. The main objective of the NRC staff’s review was to determine if the application of the Biasi CHF model along with its approved design limit could result in accurate predictions, such that there would be a 95-percent probability at the 95-percent confidence level that the hot rod in the core does not experience CBT during normal operation or AOOs.

The NRC staff’s technical evaluation is focused on determining if the model is acceptable for use in reactor safety license calculations (i.e., that the model can be trusted). To perform this review, the NRC staff chose to use the review framework described in NUREG/KM-0013, “Credibility Assessment Framework for Critical Boiling Transition Models” (Ref. 4).

3. TECHNICAL EVALUATION

This TR (EMF-2310 - Revision 1, Supplement 2P, Revision 0) is a supplement to EMF-2310, Revision 1. The original TR was initially approved by the NRC in 2001 (Ref. 5), with Revision 1 being approved in 2004 (Ref. 6). This TR provides a design limit for the Biasi CHF correlation suitable for application to HTP and HMP grids, specifically for the Post-Scram Main Steam Line Break (MSLB) analysis.

3.1. Review Framework for Critical Boiling Transition Models

This section discusses the review framework for CBT models. The framework is generated from a single main goal. That main goal is then logically decomposed into subgoals. Logical decomposition is the process of generating a set of subgoals which are logically equivalent (i.e., necessary, and sufficient) to the main goal.

This decomposition is expressed using Goal Structure Notation (GSN). Each subgoal can either be further logically decomposed into other subgoals or if no further decomposition is deemed useful, the subgoal is considered a base goal and evidence must be provided to demonstrate that the base goal is satisfied.

For CBT models, the top goal is: *The CBT model can be trusted in reactor safety analyses.* Based on the experience from multiple NRC technical staff members, a study of previous SEs, and multiple discussions with various industry experts, this goal is decomposed into various subgoals as given in the figures below, starting with the decomposition of the main goal into the three sub-goals given in Figure 1.

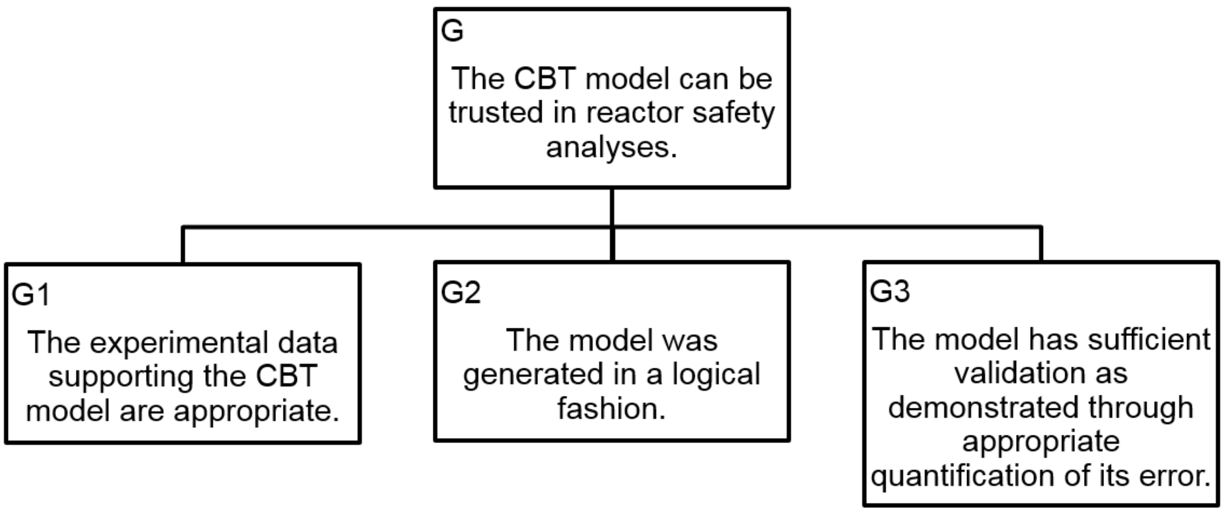

Figure 1: Decomposition of G – Main Goal

The Biasi CHF model has previously been approved by the NRC staff in its SE for EMF-2310(P)(A) Revision 1 (Ref. 5), and therefore, the NRC staff has previously determined that the correlation can be trusted for reactor safety analysis. The application of the new design limit for Biasi would not impact any of the NRC staff's findings on G1 or G2. However, it would impact G3, as the variable design limit can be thought of as an adjustment to the correlation itself and therefore re-validation is required. Additionally, as stated in Section 5.0 of the TR, "Subchannel Code," the validation of the new design limit was performed with COBRA-FLX and typically CHF correlations are used with the sub-channel code in which they have been validated. However, the application of the Biasi correlation will be XCOBRA-IIIC rather than COBRA-FLX. This concern is addressed in Goal G3.5.1.

3.2. <u>Validation of Biasi</u>

Validation is the accumulation of evidence which is used to assess the claim that a model can predict a real physical quantity (Ref. 8). Thus, validation is a never-ending process as more evidence can always be obtained to bolster this claim. However, at some point, when the accumulation of evidence is considered sufficient to make the judgment that the model can be trusted for its given purpose, the model is said to be validated. Demonstrating the model validation is appropriate and is accomplished using the five sub-goals given in Figure 2 below.

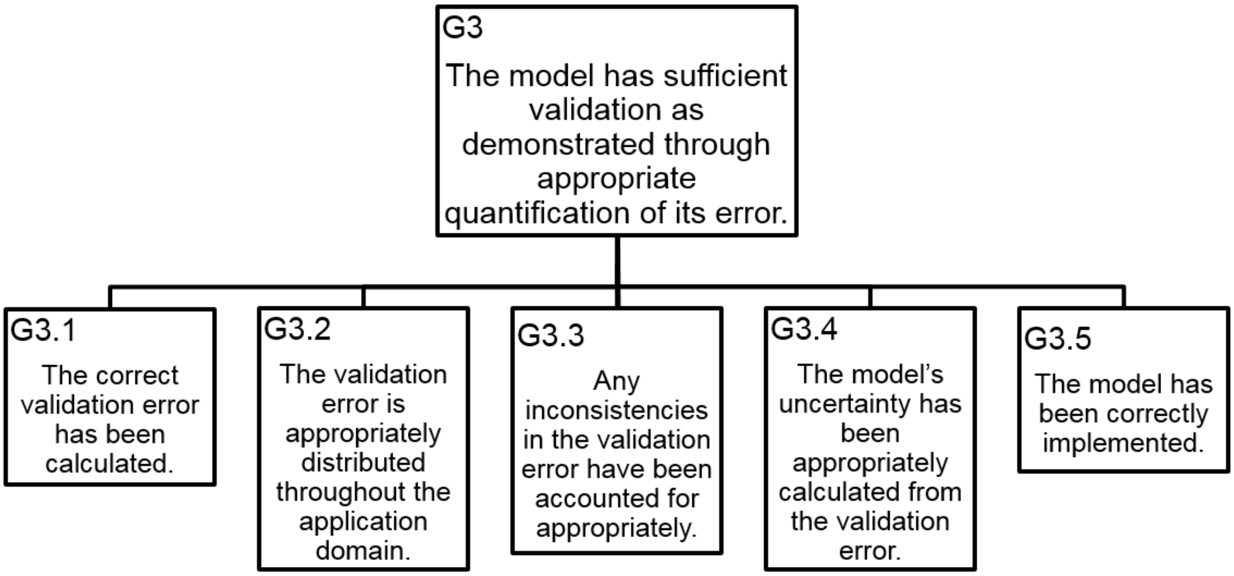

Figure 2: Decomposing G3 – Model Validation

3.2.1. Validation Error

> **Validation Error**
>
> *The correct validation error has been calculated.*
>
> G3.1, Review Framework for CBT Models

The Framatome methodology uses a **[[**

]]

[[

]] and because this metric will enable the NRC staff to ensure that the design limit remains bounding at least 95 percent of the time with a 95 percent confidence, and the NRC staff has concluded that this goal has been met.

3.2.2. Data Distribution

The second sub-goal in demonstrating that the model's validation was appropriate is to demonstrate that the data is appropriately distributed throughout the application domain. This is typically demonstrated using the six sub-goals given in Figure 3 below.

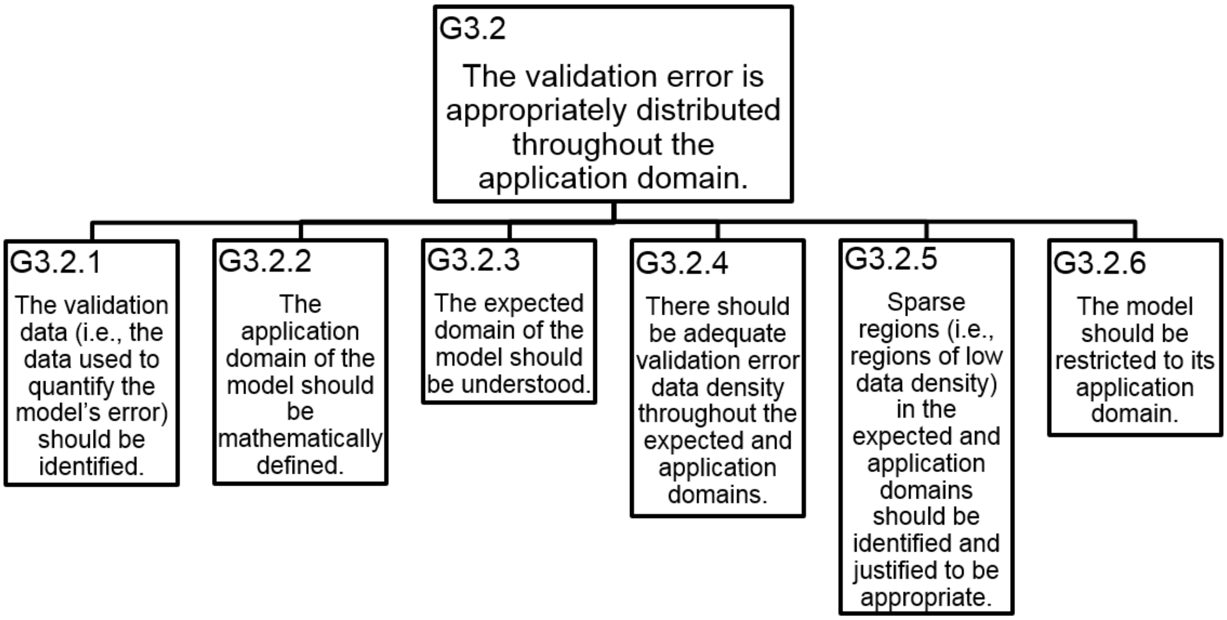

Figure 3: Decomposing G3.2 – Data Distribution

The evidence demonstrating that the following goals were met is provided below.

3.2.2.1. Validation Data

> **Validation Data**
>
> *The validation data (i.e., the data used to quantify the model's error) should be identified.*
>
> G3.2.1, Review Framework for CBT Models

The validation data used are provided in Appendix A of the TR. Because Framatome provided these data, the NRC staff has concluded that this goal has been met.

3.2.2.2. Application Domain

> **Application Domain**
>
> *The application domain of the model should be mathematically defined.*
>
> G3.2.2, Review Framework for CBT Models

The TR describes the application of a previously approved CHF correlation (Biasi) and how Framatome is applying that correlation over its application domain. As demonstrated in response to RAI-1, Framatome is **[[**

]]

[[

]] In Table 2-1, “Range of Application of Thermal Hydraulic Conditions,” of the TR, (subsequently updated in the response to RAI-1), Framatome provided the application domain for the Biasi correlation; therefore, the NRC staff has concluded that this goal has been met.

3.2.2.3. Expected Domain

Expected Domain
The expected domain of the model should be understood.
G3.2.3, Review Framework for CBT Models

In Figures 2-1, “Design Limit Application Range and Associated Penalties,” 4-1, “Test Data Domain – Pressure vs. Mass Flux,” 4-2, “Test Data Domain – Pressure vs. Quality,” and 4-3,” Test Data Domain – Mass Flux vs. Quality,” of the TR, Framatome provided plots of the expected domain of the Biasi correlation; therefore, the NRC staff has concluded that this goal has been met.

3.2.2.4. Data Density

Data Density
There should be an appropriate data density throughout the expected domain.
G3.2.4, Review Framework for CBT Models

In Figures 4-1, 4-2, and 4-3, Framatome provided plots of the expected domain of the Biasi correlation. Except for the sparse region discussed in Section 3.2.2.5 below, these plots show data density consistent with the expected data density from other CHF correlations. Therefore, the NRC staff has concluded that this goal has been met.

3.2.2.5. Sparse Regions

Sparse Regions
Sparse regions (i.e., regions of low data density) in the expected domain should be identified and justified to be appropriate.
G3.2.5, Review Framework for CBT Models

In Figures 4-1, 4-2, and 4-3, Framatome identified the expected domain of the Biasi correlation. **[[**

]], the NRC staff has concluded that this goal has been met.

3.2.2.6. Restricted Domain

Restricted Domain
The model should be restricted to its application domain.
G3.2.6, Review Framework for CBT Models

In response to RAI-1, Framatome confirmed that it will apply the Biasi correlation in such a way that a warning will be generated if it is applied outside of the application domain, and that uses of the correlation in licensing applications will be scrutinized to ensure they contain no such errors. Because Framatome has identified how the model was restricted to its application domain, the NRC staff has concluded that this goal has been met.

3.2.3. Consistent Model Error

The third sub-goal in demonstrating that the model's validation was appropriate is to demonstrate that the model error is consistent over the application domain. This is typically demonstrated using the three sub-goals as given in Figure 4 below.

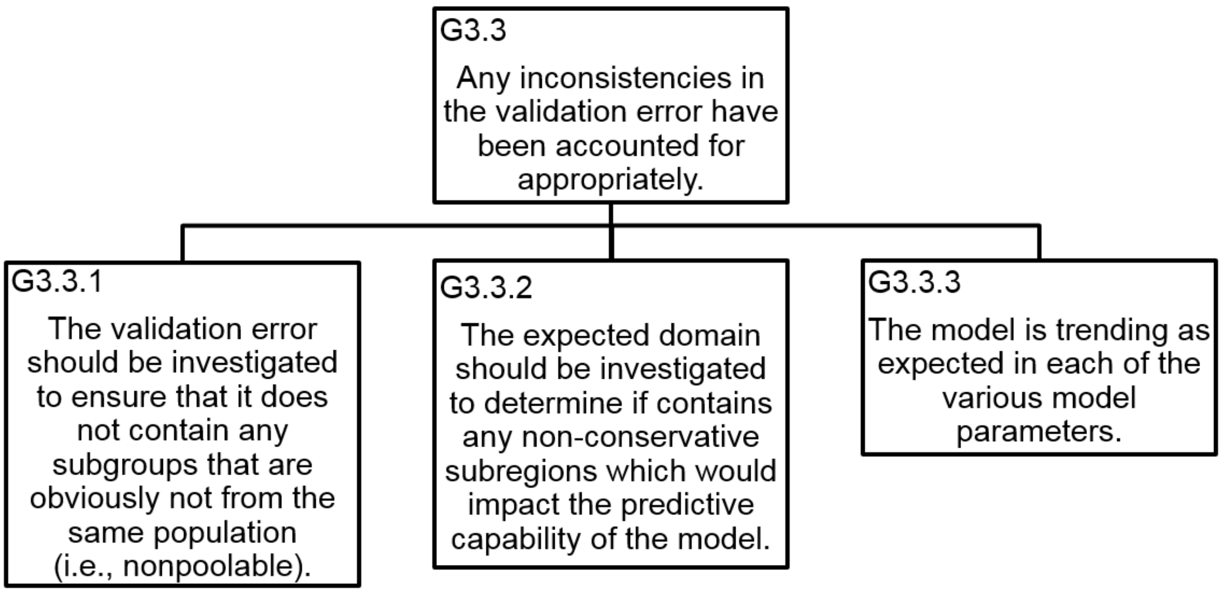

Figure 4: Decomposing G3.3 – Consistent Model Error

The evidence demonstrating the following goals were met is provided below.

3.2.3.1. Poolability

> **Poolability**
>
> *The validation error should be investigated to determine if it contains any sub-groups which are obviously not from the same population (i.e., not poolable).*
>
> G3.3.1, Review Framework for CBT Models

[[

]]

[[

]] the NRC staff found no evidence of non-poolable sub-groups in the validation error. Therefore, the NRC staff concluded that this goal has been met.

3.2.3.2. Non-Conservative Subregions

Non-Conservative Subregions
The expected domain should be investigated to determine if contains any non-conservative subregions which would impact the predictive capability of the model.
G3.3.2, Review Framework for CBT Models

As discussed in Section 7.4, “Subregion Assessment,” of the TR, **[[**

]]

[[

]]

Because Framatome has appropriately addressed the potential non-conservative subregions and there is no evidence of other potential non-conservative subregions, the NRC staff has determined that this goal has been met.

3.2.3.3. Model Trends

Model Trends
The model is trending as expected in each of the various model parameters.
G3.3.3, Review Framework for CBT Models

[[

]] the NRC staff has determined that this goal has been met.

3.2.4. Quantified Model Error

The fourth sub-goal in demonstrating that the model's validation was appropriate is to demonstrate that the model error has been appropriately quantified over the application domain. This is typically demonstrated using the three sub-goals as given in Figure 8 below.

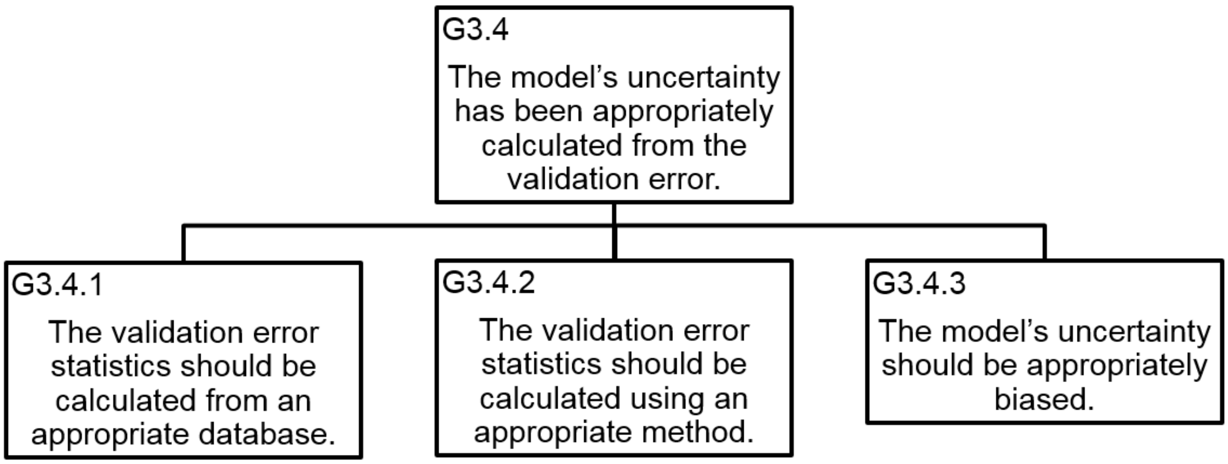

Figure 8: Decomposing G3.4 – Quantified Model Error

The evidence demonstrating the following goals were met is provided below.

3.2.4.1. Error Data Base

Error Data Base
The validation error statistics should be calculated from an appropriate database.
G3.4.1, Review Framework for CBT Models

[[

]] the NRC staff has determined that this goal has been met.

3.2.4.2. Statistical Method

Statistical Method
The validation error statistics should be calculated using an appropriate method.
G3.4.2, Review Framework for CBT Models

[[

]]
the NRC staff has determined that the goal has been met.

3.2.4.3. Appropriate Bias for Model Uncertainty

Appropriate Bias
The model's error should be appropriately biased in generating the model uncertainty.
G3.4.3, Review Framework for CBT Models

With the exception of the biases already used by Framatome **[[**

]] Because Framatome has appropriately biased the methodology where needed, the NRC staff has determined that this goal has been met.

3.2.5. Model Implementation

The fifth sub-goal in demonstrating that the model's validation was appropriate is to demonstrate that the model will be implemented in a manner consistent with its validation. This is typically demonstrated using the two sub-goals as given in Figure 9 below.

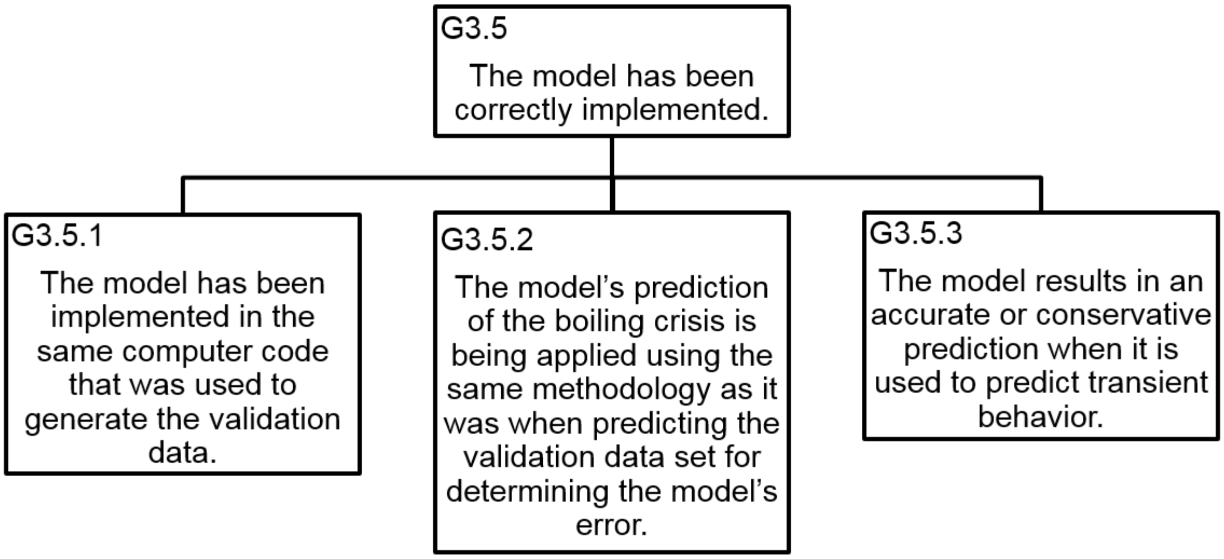

Figure 9: Decomposing G3.5– Model Implementation

The evidence demonstrating the following goals were met is provided below.

3.2.5.1. Same Computer Code

Same Computer Code
The model has been implemented in the same computer code which was used to generate the validation data.
G3.5.1, Review Framework for CBT Models

[[

]]

[[

]], the NRC staff has determined that the intent of this goal (same computer code) has been met.

3.2.5.2. Same Methodology

Same Methodology

The model's prediction of the critical boiling transition is being applied using the same methodology as it was when predicting the validation data set for determining the validation error.

G3.5.2, Review Framework for CBT Models

In general, Framatome is applying the same methodology used to perform the validation as that which will be used in a licensee's reactor safety analysis. The difference between the use of COBRA-FLX and XCOBRA-IIIC is addressed in Section 3.2.5.1 discussed above. **[[**

]]

[[

]]

[[

]]

[[

]]

[[

]]

[[

]]

Because Framatome has demonstrated that its methodology for applying the Biasi correlation is consistent with or conservative as compared to the method used when assessing the validation of the correlation, the NRC staff has determined that this goal has been met.

3.2.5.3. Transient Prediction

Transient Prediction
The model results in an accurate or conservative prediction when it is used to predict transient behavior.
G3.5.3, Review Framework for CBT Models

[[

]]

4. LIMITATIONS AND CONDITIONS

The following conditions must be applied for the use of the Biasi correlation with the associated design limit provided in Framatome's TR.

1. The Biasi correlation is limited to the domain described in Table 2-1 of the TR.

2. Application of the Biasi correlation must use the design limit as described in Section 2.0 of the TR.

3. Application of the Biasi correlation must **[[**

]]

Any application of this TR that deviates from the use of COBRA-FLX or XCOBRA-IIIC, or that significantly deviates from the modeling options used in the TR, would require new validation. Any application to a new fuel type or new mixing vane spacer type, any decrease in the design limits, or any expansion of the application domain would require NRC review and approval.

5. CONCLUSION

Based on the NRC staff's review, the staff concludes that the proposed design limit for the Biasi correlation has sufficient validation as demonstrated through appropriate quantification of its error. Therefore, the NRC staff concludes that Biasi CHF correlation and its new design limit can be trusted in reactor safety analyses subject to the limitations and conditions listed above in Section 4.0.

6. REFERENCES

1. Peters, G.A., Framatome Inc., letter to U.S. Nuclear Regulatory Commission, "Request for Review and Approval of EMF-2310, Revision 1, Supplement 2P, Revision 0, 'SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,'" NRC:22:004, February 24, 2022, ADAMS Accession No. ML22060A118 (*Non-Proprietary / Publicly Available*).

2. Framatome, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," EMF-2310, Revision 1, Supplement 2P, Revision 0, Lynchburg, VA, February 24, 2022, ADAMS Accession Nos. ML012140578 (*Proprietary Version, Non-Publicly Available*) and ML012140580 (*Nonproprietary Version, Non-Publicly Available*).

3. U.S. Nuclear Regulatory Commission, "Thermal and Hydraulic Design," Section 4.4 of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Revision 2, March 2007, ADAMS Accession No. ML070550060.

4. Kaizer, J.S., Anzalone, R., Brown, E., Panicker, M., Haider, S., Gilmer,J., Drzewiecki, T., and Attard, A., “Credibility Assessment Framework for Boiling Crisis Transition Models,” NUREG/KM-0013, 2018, ADAMS Accession ML19073A249.

5. Framatome ANP, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” EMF-2310(P)(A), Revision 1, Lynchburg, VA, May 2004, ADAMS Accession Nos. ML041810034 (*Proprietary Version, Non-Publicly Available*) and ML22060A122 (*Nonproprietary Version, Publicly Available*).

6. Framatome ANP, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” EMF-2310, Revision 1, Supplement 2P, Revision 0, Lynchburg, VA, February 2022, ADAMS Accession Nos. ML22060A161 (*Proprietary Version, Non-Publicly Available*) and ML041810033 (*Nonproprietary Version, Publicly Available*).

7. Otto, N., NRC, letter to Gary Peters, Framatome Inc., “Completeness and Withholding Determination for Framatome Topical Report, EMF-2310, Revision 1, Supplement 2P, Revision 0, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors” (L-2022-TOP-0008),” April 11, 2022, ADAMS Accession No. ML22098A182.

8. Oberkampf, W.L., and C.J. Roy, *Verification and Validation in Scientific Computing*, Cambridge University Press, Cambridge, United Kingdom, 2010.

9. Otto, N., NRC, letter to Gary Peters, Framatome Inc., “U.S. NRC Requests for Additional Information Regarding Framatome Topical Report, EMF-2310, Revision 1 Supplement 2P, Revision 0, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors” – EPID L-2022-TOP-0008,” July 1, 2022, ADAMS Accession No. ML22174A403.

10. Peters, G.A., Framatome Inc., letter to U.S. Nuclear Regulatory Commission, “Response to Request for Additional Information for EMF-2310, Revision 1, Supplement 2P, Revision 0, ‘SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,’” NRC:22:014, August 31, 2022, ADAMS Accession No. ML22245A096 (*Proprietary Version, Non-Publicly Available*) and ML22245A097 (*Nonproprietary Version, Publicly Available*).

11. Siemens, “HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel,” EMF-92-153(P)(A), Revision 1, January 2005, ADAMS Accession No. ML051020019 (*Proprietary Version, Non-Publicly Available*).

7. <u>LIST OF ACRONYMS</u>

AOO	anticipated operational occurrence
BWR	boiling water reactor
CAC	Correlation Acceptance Criteria
CBT	critical boiling transition
CE	Combustion Engineering
CFR	*Code of Federal Regulations*
CHF	critical heat flux
CP	critical power
DNB	departure from nucleate boiling

DNBR	departure from nucleate boiling ratio
G	Goal
GSN	goal structure notation
HMP	High Mechanical Performance
HTP	High Thermal Performance
MDNBR	minimum departure from nucleate boiling
MSLB	main steam line break
NRC	U.S. Nuclear Regulatory Commission
PWR	pressurized water reactor
RAI	request for additional information
SAFDL	specified acceptable fuel design limit
SE	safety evaluation
SRP	Standard Review Plan
TR	Topical Report

Attachment: Comment Resolution Table (Proprietary)

Principal Contributor: J.S. Kaizer

Date: March 30, 2023

SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors

EMF-2310, Revision 1
Supplement 2NP, Revision 0

Topical Report

February 2022

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

List of Tables

List of Figures

Nomenclature

Acronym	Definition
CAC	Correlation Acceptance Criteria
CEA	French Atomic Energy Commission
CHF	Critical Heat Flux
DNB	Departure from Nucleate Boiling
GDC	General Design Criteria
GT	Guide Tube
HMP	Framatome grid type – High Mechanical Performance
HTP	Framatome grid type – High Thermal Performance
HTRF	Columbia University's Heat Transfer Research Facility
IFM	Intermediate Flow Mixing
KATHY	Karlstein Thermal Hydraulic Test Facility
MDNBR	Minimum Departure from Nucleate Boiling Ratio
MSLB	Main Steam Line Break
NRC	Nuclear Regulatory Commission

1.0 INTRODUCTION

This report provides a design limit for the Biasi Critical Heat Flux (CHF) correlation suitable for application to High Thermal Performance (HTP) and High Mechanical Performance (HMP) grids. The Biasi correlation is approved for use in Post-Scram Main Steam Line Break (MSLB) analysis as part of the methodology described in Reference 1. This report describes the validation of a conservative design limit using design-specific CHF data. The modified Barnett correlation is no longer used for analyses covered by this supplement.

[ ]

2.0 SUMMARY AND RANGE OF APPLICABILITY

[ ]

Application of the design limit requires **ALL** of the below conditions be met:

- The thermal hydraulics conditions are within the bounds listed in Table 2-1.
- **[ ]**
- The assembly geometry is within the requirements listed in Table 2-2.
- The specific plant application is listed in Table 2-3.
- **[ ]**
- The code modeling options defined in Table 5-1 are used.

The design limit was [ ] applicable to the HTP spacer grid design. [

]

Table 2-1: Range of Application of Thermal Hydraulic Conditions

[ ]

Table 2-2: Range of Application of Fuel Assembly Geometry

[ ]

Table 2-3: Range of Application of Supported Plants

Plant
Calvert Cliffs Unit 1 (CE 14 x 14)
Calvert Cliffs Unit 2 (CE 14 x 14)
Millstone Unit 2 (CE 14 x 14)
St. Lucie Unit 1 (CE 14 x 14)
St. Lucie Unit 2 (CE 16 x 16)

Figure 2-1: Design Limit Application Range and Associated Penalties

[ ]

3.0 REGULATORY REQUIREMENTS

Steady state and transient codes and methods used for licensing basis analyses are subject to regulatory requirements and guidance specified in the Standard Review Plan (SRP) (NUREG-0800, Reference 2). SRP Section 4.4, "Thermal and Hydraulic Design" provides criteria acceptable to meet the relevant requirements of General Design Criterion (GDC) 10 of 10 CFR Part 50, Appendix A. GDC 10 requires that: "the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences." Acceptance Criterion 1.A. of SRP Section 4.4 states that for correlations used to predict CHF, there should be a 95% probability at the 95% confidence level that the hot rod in the core does not experience a Departure from Nucleate Boiling (DNB) or boiling transition condition during normal operation or Anticipated Operational Occurrences (AOOs). The design limit in this report passes this criterion when used within the specified ranges of applicability and when applied to the Biasi correlation.

4.0 CHF TESTING AND EXPERIMENTAL DATA

A summary of the experimental tests used to validate the design limit is provided in Table 4-2, Table 4-3, and Table 4-4.

4.1 *Test Facilities*

The test facilities used to obtain data for this report are summarized in Table 4-1.

- All facilities have been used in topical reports previously approved by the Nuclear Regulatory Commission (NRC), which provide descriptions of the facilities and associated quality and test procedures.
- Based on this the treatment of statistical design of the experiments; instrumentation and associated uncertainty and calibration; use of repeat test points; and treatment of test section heat losses are acceptable and consistent with previously approved correlations.

Table 4-1: Test Facility Summary

Test Campaign Prefix	Test Facility	Previous Applications
"K" "SI700/1"	KATHY - Framatome's test facility (Karlstein, Germany)	References 4, 3
"SP010"	OMEGA - French Alternative Energies and Atomic Energy Commission (CEA) test facility (Grenoble, France)	Reference 3
"SP" (except SP010)	HTRF - Columbia University's Heat Transfer Research Facility (New York, New York)	References 5, 3

4.2 *Test Data*

The Biasi correlation was originally compared to academic experimental burnout data, as described in Section 3 of Reference 6. This data was not considered during the design limit development as discussed in this report.

[ ]

[ ] have not been specifically used in correlations previous approved by the NRC. However, these tests were performed consistent with the quality programs of their respective test facilities and are considered appropriate for inclusion in this design limit assessment. Considering the large amount of data [ ] employed to develop the design limit, these tests do not impact the final conclusion supporting the appropriateness of the design limit.

Test definitions for these new tests are provided in Figure 4-4 through Figure 4-11 and Table 4-5.

Figure 4-1 through Figure 4-3 display the distribution of the test data across the pressure, mass flux, and quality design space as well as the expected domain. In most cases the expected domain is explicitly populated with test data. [ ]

Table 4-2: CHF Test Summary – Part 1: 17x17 HTP Lattice Design

[

]

Table 4-3: CHF Test Summary – Part 2: Non-17x17 HTP Lattice Design

[ ]

Table 4-4: CHF Test Summary – Part 3: 17x17 HMP Lattice Design

[ ]

Figure 4-1: Test Data Domain – Pressure vs. Mass Flux

Figure 4-2: Test Data Domain – Pressure vs. Quality

[ ]

Figure 4-3: Test Data Domain – Mass Flux vs. Quality

Table 4-5: Radial Power Distributions of CHF Tests

[ ]

Figure 4-4: Radial Geometry of Test SP660

[

]

Figure 4-5: Axial geometry of CHF test SP660

Figure 4-6: Radial Geometry for Test SP010

[

]

Figure 4-7: Axial Geometry of CHF Test SP010

Figure 4-8: Radial Geometry of Test SI700/1

[ ]

Figure 4-9: Axial Geometry of CHF Test SI700/1

Figure 4-10: Radial Geometry of Test K8800

Figure 4-11: Axial Geometry of CHF Test K8800

4.3 *Experimental Considerations*

This section provides justifications for common assumptions made during the evaluation of CHF data.

Test Facility Comparison

As previously demonstrated in the response to RAI-SNPB-02 to Reference 3, data obtained from [

] Therefore, combining data from these facilities is not a concern. This conclusion remains true for the current application.

Test Section Heat Loss

As previously demonstrated in the response to RAI-SNPB-05 to Reference 3, test section heat losses [

]

Transient Behavior

Consistent with prior applications (Reference 3), it is common practice to assume the CHF during a transient situation will be exceeded when the local instantaneous conditions are equivalent to those causing its occurrence under steady state conditions. Therefore, transient CHF is not considered as it is bounded by the steady state testing.

Training and Validation Data

As discussed in Section 6.0 the Biasi correlation was developed externally using academic experimental burnout data.

The validation of the Biasi correlation and design limit development was performed using [.]

The statistical analysis provided in Section 7.0, further demonstrating the acceptability of the design limit, [ ]

Simple Support Grids

As previously demonstrated in the response to RAI-SNPB-08 to Reference 3, the use of simple support grids [ ] This conclusion remains true for the current application.

5.0 SUBCHANNEL CODE

The design limit was developed and verified using the subchannel code COBRA-FLX, which has been reviewed and approved by the U.S. NRC for application to nuclear core thermal-hydraulic analysis for steady-state and transient conditions in Reference 7.

MSLB analyses performed in accordance with Reference 1 use the XCOBRA-IIIC subchannel solver. While the COBRA family of sub-channel codes predict local conditions similarly, small code-to-code differences are expected. Therefore, the design limit defined in Section 2.0, [ ]

Previous code comparisons when applying a correlation design limit developed with COBRA-FLX to XCOBRA-IIIC have demonstrated [

]

The parameters in Table 5-1 are to be used when applying the Biasi correlation for safety analysis in XCOBRA-IIIC.

Table 5-1: XCOBRA-IIIC Modeling Options

[ ]

6.0 CORRELATION DEFINITION

The Biasi correlation was developed in Reference 6 and is part of the method approved in Reference 1. The correlation was not modified for this application.

The design limit was developed using the methods described in [

]

The conservatism of this design limit is demonstrated in Section 7.0.

7.0 CORRELATION ASSESSMENT AND STATISTICAL ANALYSIS

This section provides a summary of the comparison of the data predicted by the correlation to the CHF test data.

7.1 *Acceptance Criteria*

Traditionally, a ratio of the predicted heat flux to the measured heat flux (P/M) is used to characterize the predictive capability of the correlation, and a design limit is selected to bound at least 95% of the P/M population (assuming poor performing points are randomly distributed). The validation error as given by the CHF measured-to-predicted values are determined at the MDNBR location as predicted by the correlation.

This analysis makes two minor deviations from this standard practice.

[ ]

[ ]

7.2 *Analysis Overview*

The data analysis was performed as follows:

- Each data point was modeled in COBRA-FLX to calculate the predicted heat flux and develop a P/M ratio. A summary of these results is presented in Table 7-1. The full results are presented in Appendix A.

[ ]

- The statistics of the resulting population were inspected for concerns, including residual trends and non-conservative subregions.

7.3 *Results*

A summary of the test statistics is shown in Table 7-1. “Failing Points” are those for which the measured heat flux is not predicted conservatively relative to the design limit. Results are provided both with and without the penalties defined in Figure 2-1.

Figure 7-1 through Figure 7-4 present a graphical representation of the data.

Figure 7-1 shows the distribution of data. [

]

[

]

Table 7-1: Overall Statistics of CHF Test Data Predications

[ ]

Figure 7-1: CAC Distribution

Figure 7-2: Unpenalized CAC vs. Equilibrium Quality

[ ]

Figure 7-3: Unpenalized CAC vs. Mass Flux

Figure 7-4: Unpenalized CAC vs. Pressure

7.4 *Subregion Assessment*

An inspection of the data was performed to ensure that the correlation statistics behaved similarly across all subregions of the application range.

Subregion results based on test configurations are presented in Table 7-2 and show no concerning trends.

Subregion results based on operating conditions are presented in Table 7-3. [

]

[

]

Table 7-2: Test Configuration Subregion Assessment

[ ]

Table 7-3: Operating Condition Subregion Assessment (Unpenalized)

[ ]

Table 7-4: Operating Condition Subregion Assessment (Penalized)

[ ]

7.5 *Intended Application*

The design limit defined herein will be used to support MSLB analysis for the plants identified in Table 2-3 for the HTP 14 and HTP 16 fuel assembly designs.

Assembly Design

All key geometry values of the HTP fuel assembly are within the ranges supported by the design limit as specified in Table 2-2. The HTP assembly has two grid types relevant to DNB analysis in the heated region.

- The bottom most grid is an HMP structural grid. [

  ] The HMP data compared favorably against the design limit, as seen in Table 7-2.
- All other grids in the heated region are of the HTP design. HTP data [

  ] and is predicted favorably.

Therefore, the Biasi design limit is applicable to DNB calculations spanning the entire HTP assembly.

Methodology

The Biasi correlation is approved for use in MSLB analyses per Reference 1. This method is typically implemented by modeling each assembly in the limiting stuck rod region as a single channel; assemblies outside this region are lumped into two additional channels.

To ensure that the modeling assumptions used in the reload are conservative relative to those used in the development of the design limit, [

]

As described in Section 5.0, the Reference 1 methodology is implemented using XCOBRA-IIIC; therefore, an appropriate correction factor has been applied.

Table 7-5: MDNBR Correction Factor

Plant Type	Correction Factor
CE 14x14	0.880
CE 16x16	0.826

8.0 QUALITY ASSURANCE PROGRAM

The Biasi design limit and supporting analysis was performed under a quality assurance program that meets the regulatory requirements of 10 CFR Part 50 Appendix B.

9.0 REFERENCES

1. EMF-2310(P)(A) Revision 1, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors.”

2. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Plants: LWR Edition,” March 2007.

3. ANP-10341P-A Revision 0, “The ORFEO-GAIA and ORFEO-NMGRID Critical Heat Flux Correlations.”

4. ANP-10269P-A Revision 0, “The ACH-2 CHF Correlation for the U.S. EPR.”

5. EMF-92-153(P)(A) Revision 1, “HTP: Departure from Nucleate Boiling Correlation for High Thermal Performance Fuel.”

6. “Studies on Burnout, Part 3 - A New Correlation for Round Ducts and Uniform Heating and its Comparison with World Data,” L. Biasi et al., *energia nucleare*, vol. 14, n. 9, September 1967.

7. ANP-10311P-A Revision 1, “COBRA-FLX: A Core Thermal-Hydraulic Analysis Code.”

8. [

]

APPENDIX A

Appendix A is proprietary in its entirety.

Correspondence

EMF-2310, Revision 1, Supplement 2NP-A, Revision 0 framatome

February 24, 2022
NRC:22:004

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Request for Review and Approval of EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors"

Framatome Inc. (Framatome) requests the NRC's review and approval of the topical report EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors" for referencing in licensing actions. The topical report EMF-2310, Revision 1, Supplement 2P, Revision 0, provides a justification for the use of a design limit for the Biasi Critical Heat Flux (CHF) correlation suitable for application to High Thermal Performance (HTP) and High Mechanical Performance (HMP) grids in Framatome PWR methodologies.

Framatome would appreciate NRC approval of this topical report by August 2022.

Framatome considers some of the material contained in Enclosure 1 to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding of information from public disclosure.

There are no regulatory commitments within this letter or its enclosures.

If you have any questions related to this submittal please contact Mr. Morris Byram, Product Manager, Licensing & Regulatory Affairs. He may be reached by telephone at 434-221-1082 or by e-mail at Morris.Byram@framatome.com.

Sincerely,

Gary Peters, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: N. Otto
Project 728

Enclosures:

1 EMF-2310, Revision 1, Supplement 2, Revision 0 (PROPRIETARY)
2 EMF-2310, Revision 1, Supplement 2, Revision 0 (NON-PROPRIETARY)
3 Affidavit

From:	ELLIOTT Gayle (FRA-CORP)
To:	ELDER Heidi (FRA-CORP)
Cc:	PETERS Gary (FRA-CORP)
Subject:	FW: U.S. NRC Requests for Additional Information Regarding Framatome Topical Report, EMF-2310, Revision 1 Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors" – EPID L-2022-TOP-0008
Date:	Friday, July 1, 2022 10:50:33 AM

Incoming NRC mail to assign number, put in ADOM and Documentum when you're available.

Gayle

From: Otto, Ngola <Ngola.Otto@nrc.gov>
Sent: Friday, July 01, 2022 10:49 AM
To: PETERS Gary (FRA-CORP) <gary.peters@framatome.com>
Cc: Chang, Richard <Richard.Chang@nrc.gov>; Lukes, Robert <Robert.Lukes@nrc.gov>; BYRAM Morris (FRA-CORP) <morris.byram@framatome.com>; ELLIOTT Gayle (FRA-CORP) <gayle.elliott@framatome.com>
Subject: U.S. NRC Requests for Additional Information Regarding Framatome Topical Report, EMF-2310, Revision 1 Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors" – EPID L-2022-TOP-0008

Security Notice: Please be aware that this email was sent by an external sender.

Mr. Gary Peters, Director
Licensing and Regulatory Affairs
Framatome, Inc.
3315 Old Forest Road
Lynchburg, VA 24501

Mr. Peters,

This e-mail serves as a cover letter for the transmittal of Requests for Additional Information (RAIs).

By letter dated February 24, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22060A118), Framatome Inc. (Framatome) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review and approval Topical Report (TR) EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA [Loss-of-Coolant Accident] Methodology for Pressurized Water Reactors" (ADAMS Package Accession No. ML22060A164).

With respect to the review of EMF-2310, Revision 1, Supplement 2P, Revision 0, I have placed an electronic version of the RAIs in the BOX.com folder for your review. Morris Byram, Framatome, has been given access to the folder. The RAIs have also been placed in ADAMS as non-public so it can be declared an Official Agency Record in the future. When responding to this RAI, please confirm if there is any proprietary information in the RAI and/or the response. Your response, provided via letter under authorized signature, will generate the ADAMS version of the RAIs based on the proprietary nature of the document.

Our current schedule for this TR review assumes that Framatome will provide responses to the RAIs by August 10, 2022.

If you have any questions or would like to discuss the RAIs with staff to ensure you understand the NRC's request, please let me know.

This e-mail will be uploaded in ADAMS and declared publicly available.

Ngola Otto
Project Manager, Licensing Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation
US Nuclear Regulatory Commission
e-mail: Ngola.Otto@nrc.gov
phone: (301) 415-6695

Docket No. 99902041
ADAMS Accession Nos.:
ML22174A354 (Package)
ML22174A403 (e-mail transmittal)
ML22174A362 (RAI Questions - Proprietary) via BOX

U.S. NUCLEAR REGULATORY COMMISSION

REQUESTS FOR ADDITIONAL INFORMATION

FRAMATOME TOPICAL REPORT EMF-2310, REVISION 1, SUPPLEMENT 2P,

REVISION 0, "SRP CHAPTER 15 NON-LOCA METHODOLOGY FOR

PRESSURIZED WATER REACTORS"

PROJECT NO. 99902041

EPID L-2022-TOP-0008

1.0 INTRODUCTION

By letter dated February 24, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22060A118), Framatome Inc. (Framatome) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review and approval Topical Report (TR) EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA [Loss-of-Coolant Accident] Methodology for Pressurized Water Reactors" (ADAMS Package Accession No. ML22060A164). The purpose of this report was to describe the design limit for the Biasi critical heat flux (CHF) correlation and use for predicting the CHF performance of the High Thermal Performance and High Mechanical Performance grids under certain conditions.

During this review, an in-person regulatory audit for understanding was conducted on June 13-16, 2022 (ADAMS Accession No. ML22137A271). The NRC staff requests for additional information from the review of EMF-2310 are provided below.

2.0 REGULATORY BASIS

General Design Criterion (GDC) 10, "Reactor Design," in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic licensing of production and utilization facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," is the principal regulation associated with this report. This criterion introduces the concept of specified acceptable fuel design limits (SAFDLs). In essence, SAFDLs are those limits placed on certain variables to ensure that the fuel does not fail. One such SAFDL is associated with departure from nucleate boiling (DNB). Because the decrease in heat transfer following DNB could result in fuel failure, a SAFDL is used to demonstrate that critical power does not occur during normal operation and anticipated operational occurrences (AOOs). Therefore, fuel failure is precluded during normal operation and AOOs.

Standard Review Plan Section 4.4, "Thermal and Hydraulic Design," includes the SAFDLs used in accounting for the uncertainties involved in developing and predicating DNB performance model and ensuring that fuel failure is precluded:

There should be a 95-percent probability at the 95-percent confidence level that the hot rod in the core does not experience a DNB or boiling crisis condition during normal operation or AOOs.

3.0 REQUEST FOR ADDITIONAL INFORMATION

In order to determine that the Biasi correlation can satisfy the associated SAFDL, the NRC staff requests the following information.

1) In Table 2-1, "Range of Application of Thermal Hydraulic Conditions," of the TR, Framatome provided the application domain of the Biasi correlation. **[[**

   ]] Additionally, please discuss how the correlation will be restricted to use in its application domain.

2) Framatome has indicated plans to use the Biasi correlation in **[[**

   ]]

3) Please discuss why the **[[**

   ]]

4) Please provide the technical basis and justification for the Minimum DNB ratio (MDNBR) correlation factor for CE 14x14 and CE 16x16 fuel discussed in Table 7-5, "MDNBR Correction Factor," of the TR.

framatome

August 31, 2022
NRC:22:014

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to Request for Additional Information for EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors"

Framatome Inc. (Framatome) requested the NRC's review and approval of the topical report EMF-2310, Revision 1, Supplement 2P, Revision 0, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors" in Reference 1. The NRC provided a Request for Additional Information (RAI) in Reference 2. This letter submits a response to the Reference 2 RAI.

Framatome considers some of the material contained in Enclosure 1 to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed to support withholding of information from public disclosure.

There are no regulatory commitments within this letter or its enclosures.

If you have any questions related to this submittal please contact Mr. Morris Byram, Product Manager, Licensing & Regulatory Affairs. He may be reached by telephone at 434-221-1082 or by e-mail at Morris.Byram@framatome.com.

Sincerely,

Gary Peters

Gary Peters, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: N. Otto
Project 728

References:

1. Letter NRC-22-004, Gary Peters (Framatome Inc.) to Document Control Desk (NRC), "Request for Review and Approval of EMF-2310, Revision 1, Supplement 2P, Revision 0, 'SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors'," dated February 24, 2022.
2. Letter (email), Ngola Otto (NRC) to Gary Peters (Framatome Inc.), "U.S. NRC Requests for Additional Information Regarding Framatome Topical Report, EMF-2310, Revision 1 Supplement 2P, Revision 0, 'SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors' – EPID L-2022-TOP-0008'," dated July 1, 2022.

Enclosures:

1 EMF-2310, Revision 1, Supplement 2, Revision 0, Q1P, Revision 0 (PROPRIETARY)
2 EMF-2310, Revision 1, Supplement 2, Revision 0, Q1NP, Revision 0 (NON-PROPRIETARY)
3 Affidavit

SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors

EMF-2310, Revision 1,
Supplement 2, Revision 0
Q1NP, Revision 0

Topical Report

August 2022

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

List of Tables

List of Figures

Nomenclature

Acronym	Definition
CE	Combustion Engineering
CHF	Critical Heat Flux
DNB	Departure from Nucleate Boiling
LOCA	Loss of Coolant Accident
MDNBR	Minimum Departure from Nucleate Boiling Ratio
MSLB	Main Steam Line Break
RAI	Request for Additional Information
SRP	Standard Review Plan
TR	Topical Report

Introduction

Requests for additional information (RAIs) related to Topical Report (TR) Supplement EMF-2310, Revision 1, Supplement 2P, Revision 0 are documented in Reference 1. Responses to these RAIs are provided herein.

1.0 RAI 1

Question:

In Table 2-1, “Range of Application of Thermal Hydraulic Conditions,” of the TR, Framatome provided the application domain of the Biasi correlation. [

] Additionally, please discuss how the correlation will be restricted to use in its application domain.

Response:

[

] The original range of application of thermal hydraulic conditions for the Biasi CHF correlation is defined in Reference 3, shown in Table 1-1. The application domain used by Framatome is defined in Table 2-1 of the Topical Supplement, Reference 2. [

]

Table 1-1: Original Biasi Range of Application of Thermal Hydraulic Conditions

Parameter	Units	Minimum Value	Maximum Value
Pressure	ata	2.7	140
	psia	39.7	2057
Mass Flux	g/sec-cm2	10	600
	Mlbm/hr-ft2	0.0737	4.424
Quality In	Fraction	n/a	0
Quality Out	Fraction	$\frac{1}{1+{\rho_l}/{\rho_g}}$	1

Table 1-2: Updated Biasi Range of Application of Thermal Hydraulic Conditions

[

]

In the Table 2-1 of the Topical Supplement, Reference 2, the minimum mass flux value was defined to be [

]

Figure 7-3 in the Topical Report Supplement, Reference 2, shows the relationship between the mass flux and the Correlation Acceptance Criteria (CAC). The CAC is defined in the Topical Report Supplement, Reference 2. [

]

Figure 1-1 and Figure 1-2 show the mass flux with respect to quality and pressure, respectively. [

]

[ ]

Figure 1-1 Data Domain –Quality vs. Mass Flux

[ ]

Figure 1-2 Data Domain – Mass Flux vs. Pressure

Figure 1-3 comes from Figure 2-1 in the Topical Report Supplement, Reference 2, with the addition of the original Biasi range of application and the Framatome application domain explicitly shown. [

]

[ ]

Figure 1-3 Design Limit Application Range and Associated Penalties

[

]

With regard to restricting the use of the correlation to its application domain, Figure 1-3, it is standard practice for the analyst to check the application limits of the CHF correlation being used. Additionally, it is standard practice to implement error checking in the code and for the analyst to check for these warnings for the CHF correlation being applied outside of the allowed application domain.

Due to RAI 1 resolution, the following updates were made to the EMF-2310 Supplement 2P Topical Report (Shown in Section 6.0 of this document):

2.0 RAI 2

Question:

Framatome has indicated plans to use the Biasi correlation in [

]

Response:

A similar argument may be made as is provided for the ORFEO-GAIA and ORFEO-NMGRID CHF correlations in the response to RAI-SNPB-09 from Reference 4. The local quality is dependent on the pressure, mass flux, inlet subcooling, and bundle power. [

]

[ ]

[ ]

Figure 2-1: Test Data Domain – Pressure vs. Quality (2, Figure 4-2), With MSLB Statepoints

[

]

Table 2-1: MSLB Statepoints with DNB Margin Comparison

[ ]

3.0 RAI 3

Question:

Please discuss why the [

]

Response:

The COBRA-FLX code was initially used to take advantage of existing automation for data manipulation and design limit analysis of the CHF data. Using the Biasi correlation within the XCOBRA-IIIC code minimizes changes to the internal analytical processes and licensing bases of existing customers.

[

]

Figure 3-1: Unpenalized XCOBRA-IIIC and COBRA-FLX CAC Comparison

4.0 RAI 4

Question:

Please provide the technical basis and justification for the Minimum DNB ratio (MDNBR) correlation factor for CE 14x14 and CE 16x16 fuel discussed in Table 7-5, “MDNBR Correction Factor,” of the TR.

Response:

The following methodology was used for calculating the Biasi geometry correction factor for assembly-based CHF calculations. The Biasi Correlation is given by the following equations (Reference 3):

$$\Phi_0 = \frac{1.883 \cdot 10^3}{D^\alpha \cdot G^{\frac{1}{6}}}\left[\frac{y(P)}{G^{\frac{1}{6}}} - X_0\right] \text{ for low quality cases}$$

$$\Phi_0 = \frac{3.78 \cdot 10^3 \cdot h(p)}{D^\alpha \cdot G^{0.6}}[1 - X_0] \text{ for high quality cases}$$

Where

$$\frac{1}{1 + \frac{e_l}{e_g}} < X_0 < 1$$

$$y(P) = 0.7249 + 0.099P \cdot \exp(-0.032 \cdot P)$$

$$h(P) = -1.159 + 0.149P \cdot \exp(-0.019 \cdot P) + \frac{8.99 \cdot P}{10 + P^2}$$

[ ]

A conservative assessment of the impact of the hydraulic diameter term is to take the ratio of **[ ]** for the sub-channel to that of the assembly to calculate a Correction Factor (shown below) **[ ]**

[ ]

The pertinent geometric parameters are shown in the Table 4-1 below. These are used for the correlation factors for CE 14x14 and CE 16x16 fuel discussed in Table 7-5, “MDNBR Correction Factor,” of Reference 2 because they are the most conservative correction factors found from the analysis.

Table 4-1: Correction Factors for CE 14 and CE 16 Fuel Types

[ ]

5.0 REFERENCES

1. NRC Letter (email), “Request for Additional Information Regarding Framatome Inc. Topical Report EMF-2310, Revision 1, Supplement 2P, Revision 0, ‘SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors’ (EPID: L-2022-TOP-0008),” July 1, 2022.
2. EMF-2310, Revision 1, Supplement 2P, Revision 0, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” February 2022.
3. “Studies on Burnout, Part 3 - A New Correlation for Round Ducts and Uniform Heating and its Comparison with World Data,” L. Biasi et al., *energia nucleare*, vol. 14, n. 9, September 1967.
4. ANP-10341P-A, Revision 0, The ORFEO-GAIA and ORFEO-NMGRID Critical Heat Flux Correlations, Framatome Inc., September 2018.

6.0 TOPICAL REPORT CHANGES

Due to RAI resolution, markups to EMF-2310 Supplement 2P were required. To facilitate an efficient review, changes to the Topical Report Supplement are provided below.

Table 2-1: Range of Application of Thermal Hydraulic Conditions

[ ]

Figure 2-1: Design Limit Application Range and Associated Penalties

[

]

[

]

Figure 4-1: Test Data Domain – Pressure vs. Mass Flux

Figure 4-3: Test Data Domain – Mass Flux vs. Quality

Summary of Changes

Document Location	Description of Change	Reference
Table 2-1	Markup from Section 6 of Reference incorporated	EMF-2310, Revision 1, Supplement 2, Revision 0, Q1P, Revision 0
Figure 2-1	Markup from Section 6 of Reference incorporated	EMF-2310, Revision 1, Supplement 2, Revision 0, Q1P, Revision 0
Figure 4-1	Markup from Section 6 of Reference incorporated	EMF-2310, Revision 1, Supplement 2, Revision 0, Q1P, Revision 0
Figure 4-3	Markup from Section 6 of Reference incorporated	EMF-2310, Revision 1, Supplement 2, Revision 0, Q1P, Revision 0