framatome

February 15, 2018
NRC:18:004

PRDJ0728

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

2017 - Annual Reporting of Changes and Errors in Emergency Core Cooling Systems (ECCS) Evaluation Models

Ref. 1: Letter, Gary Peters (AREVA Inc.) to Document Control Desk (NRC), "2016 - Annual Reporting of Changes and Errors in Emergency Core Cooling Systems (ECCS) Evaluation Models," NRC:17:007, February 1, 2017.

Attached is a summary report of changes and error corrections implemented in the Framatome Inc. (Framatome, formerly AREVA Inc.) Emergency Core Cooling Systems (ECCSs) evaluation models for the period of January 1, 2017 to December 31, 2017. Reference 1 provided reporting for the previous year.

Framatome considers the Boiling Water Reactor (BWR) and Pressurized Water Reactor (PWR) ECCS evaluation models to include both the codes and the methodology for using the codes. Changes to inputs that result from fuel or plant changes, and that are treated according to the methodology, are not considered model changes and, therefore, are not reported in the attachment. Changes in peak cladding temperatures (PCTs) due to loss of coolant accident (LOCA) evaluation model changes and errors are reported on a plant specific basis by Framatome to the affected licensees. The licensees have the obligation under 10 CFR 50.46 to report the nature of changes and errors affecting PCT. The report in this letter is provided for information only.

If you have any questions related to this information, please contact Mr. Alan B. Meginnis, Product Licensing Manager, by telephone at (509) 375-8266, or by e-mail at Alan.Meginnis@framatome.com.

Sincerely,

Gary Peters, Director
Licensing & Regulatory Affairs
Framatome Inc.

cc: J. G. Rowley
Project 728

Framatome Inc.
3315 Old Forest Road
Lynchburg, VA 24501
Tel: (434) 832-3000

www.framatome.com

YG01
NRR

Attachments:
1. Attachment A- Listing of Framatome LOCA Evaluation Models
2. Attachment B- Annual Reporting of Framatome LOCA Evaluation Model Changes and Error Corrections (January 1, 2017- December 31, 2017)

Attachment A

Listing of Framatome LOCA Evaluation Models

EXEM BWR-2000 Large and Small Break LOCA Evaluation Model

This model is applicable to jet-pump boiling water reactors for both large and small break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2361PA, Revision 0.

CRAFT2 PWR Large Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for large break LOCA analyses of zircaloy clad fuel. The NRC approved topical report for this evaluation model is BAW-10104PA, Revision 5.

CRAFT2 PWR Small Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for small break LOCA analyses of zircaloy clad fuel. The NRC approved topical report for this evaluation model is BAW-10154PA, Revision 0.

RELAP5/MOD2-B&W Once Through Steam Generator Large and Small Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for large and small break LOCA analyses of zircaloy or M5® clad fuel. The NRC approved topical report for this evaluation model is BAW-10192PA, Revision 0. The NRC has approved this evaluation model for M5® clad fuel in BAW-10227PA, Revision 0.

RELAP5/MOD2-B&W Re-Circulating Steam Generator Large and Small Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for large and small break LOCA analyses. The NRC approved topical report for this evaluation model is BAW-10168PA, Revision 3.

SEM/PWR-98 PWR Large Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for large break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2087PA, Revision 0.

ANF-RELAP PWR Small Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 2, 3, and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for small break LOCA analyses. The NRC approved topical report for this evaluation model is XN-NF-82-49PA, Revision 1, Supplement 1.

S-RELAP5 PWR Small Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 2, 3, and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for small break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2328PA, Revision 0 and Supplement 1 PA Revision 0.

Realistic PWR Large Break LOCA Model

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering 2x4 designed pressurized water reactors for large break LOCA analyses. The NRC approved topical reports for this evaluation model are EMF-2103PA, Revision 0 and EMF-2103PA, Revision 3.

Attachment B

Annual Reporting of Framatome LOCA Evaluation Model Changes and Error Corrections

(January 1, 2017- December 31, 2017)

EXEM BWR-2000 Large and Small Break LOCA Evaluation Model

This model is applicable to jet-pump boiling water reactors for both large and small break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2361PA, Revision 0.

The Evaluation Model consists of three computer codes:

(1) RELAX to compute the system and hot channel response during blowdown and to calculate the time for refill of the lower plenum and reflood of the core,
(2) HUXY to calculate the heatup of the peak power plane, and
(3) RODEX2 to determine the rod conditions at the start of the transient.

There were no evaluation model changes or error corrections made during the reporting period.

CRAFT2 PWR Large Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for large break LOCA analyses of zircaloy clad fuel. The NRC approved topical report for this evaluation model is BAW-10104PA, Revision 5.

The Evaluation Model consists of five computer codes:

(1) CRAFT2 to compute the system and core response during blowdown,
(2) REFLOD3 to calculate the time for refill of the lower plenum and core reflood rate,
(3) CONTEMPT to compute the containment pressure response,
(4) FLECSET to calculate the hot pin heat transfer coefficients, and
(5) THETA1-B to determine the hot pin thermal response for the entire transient. An NRC-approved fuel code (currently TAC03) is used to supply the fuel rod steady-state conditions at the beginning of the transient.

There were no evaluation model changes or error corrections made during the reporting period.

CRAFT2 PWR Small Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for small break LOCA analyses of zircaloy clad fuel. The NRC approved topical report for this evaluation model is BAW-10154PA, Revision 0.

The Evaluation Model consists of three computer codes:

(1) CRAFT2 to compute the system and core response during blowdown,
(2) FOAM2 to calculate the core mixture level and average channel steaming rate, and
(3) THETA 1-B to determine the hot pin thermal response for the entire transient. An NRC-approved fuel code (currently TAC03) is used to supply the fuel rod steady-state conditions at the beginning of the transient.

There were no evaluation model changes or error corrections made during the reporting period.

RELAP5/MOD2-B&W Once Through Steam Generator Large and Small Break LOCA Evaluation Model

This model is applicable to all B&W designed pressurized water reactors for large and small break LOCA analyses of zircaloy or M5® clad fuel. The NRC approved topical report for this evaluation model is BAW-10192PA, Revision 0 Supplement 1 Revision 0. An NRC-approved fuel code (currently BAW-10162PA, TAC03 or BAW-10184PA, GDTACO) is used to supply the fuel rod steady-state conditions at the beginning of the small or large break LOCA. These codes are approved for use with M5® cladding via the safety evaluation report on BAW-10227PA. The NRC has approved BAW-10192PA, Revision 0 evaluation model for M5® clad fuel in BAW-10227PA, Revision 0.

The large break LOCA Evaluation Model consists of four computer codes:

(1) BAW-10164PA, RELAP5/MOD2-B&W to compute the system, core, and hot rod response during blowdown.
(2) BAW-10171PA, REFLOD3B to calculate the time for refill of the lower plenum and core reflood rate.
(3) BAW-10095A, CONTEMPT to compute the containment pressure response, and
(4) BAW-10166PA, BEACH (RELAP5/MOD2-B&W reflood heat transfer package) to determine the hot pin thermal response during refill and reflood phases.

The small break LOCA Evaluation Model consists of two codes:

(1) BAW-10164PA, RELAP5/MOD2-B&W to compute the system, core, and hot rod response during the transient, and
(2) BAW-10095A, CONTEMPT to compute the containment pressure response, if needed.

There was one evaluation model error correction made during the reporting period.

M5® LOCA Swelling and Rupture Model (SRM) Update

The M5® fuel clad swelling and rupture model (SRM) is used in several of the Framatome LOCA methodologies. The SRM was approved by the NRC in the early 2000s as part of the M5® Licensing Topical Report, BAW-10227PA, Rev. 1. Additional M5® cladding rupture test data has been obtained since the model's approval. Upon review of the data and the SRM's use in LOCA analysis, it was determined that certain aspects of the model would be impacted. Following the same approach as the original model, an updated M5® SRM was developed to take into account the updated test database. The model changes do not change the predicted occurrence or conditions at the time of rupture, but would impact the post-rupture cladding characteristics for certain rupture temperatures.

Each plant with an analysis of record (AOR) which was performed with a LOCA methodology using the M5® SRM was screened relative to the predicted rupture temperature. If the AOR had rupture temperatures less than the range of the model changes, the post-rupture conditions and, therefore, transient results would not change. For this situation, a 0ºF peak clad temperature (PCT) estimate was assigned. If the AOR had rupture temperatures within the range of change, a more detailed evaluation of the expected change in the predicted post-rupture conditions was performed to assess the PCT impact. Supporting analyses were performed as necessary.

The B&W designed plants SBLOCA and LBLOCA analysis PCT estimate was 0ºF.

RELAP5/MOD2-B&W Re-Circulating Steam Generator Large and Small Break LOCA Evaluation Model

This model is applicable to Westinghouse-designed 3 and 4 loop pressurized water reactors and Combustion Engineering-designed pressurized water reactors for large and small break LOCA analyses. The NRC approved topical report for this evaluation model is BAW-10168PA, Revision 3.

This methodology is no longer used.

SEM/PWR-98 PWR Large Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for large break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2087PA, Revision 0.

The SEM/PWR-98 large break LOCA Evaluation Model consists of four primary computer codes:

(1) RELAP4 to compute the system and hot channel response,
(2) RFPAC to compute the containment pressures, reflood rates, and axial shape factors,
(3) TOODEE2 to calculate the hot rod heatup, and
(4) RODEX2 to determine the rod conditions at the start of the transient.

There were no evaluation model changes or error corrections made during the reporting period.

ANF-RELAP PWR Small Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 2, 3, and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for small break LOCA analyses. The NRC approved topical report for this evaluation model is XN-NF-82-49PA, Revision 1, Supplement 1.

The ANF-RELAP small break LOCA Evaluation Model consists of three computer codes:

(1) ANF-RELAP to compute the system response,
(2) TOODEE2 to calculate the hot rod heatup, and
(3) RODEX2 to determine the rod conditions at the start of the transient.

There were no evaluation model changes or error corrections made during the reporting period.

S-RELAP5 PWR Small Break LOCA Evaluation Model

This model is applicable to Westinghouse designed 2, 3, and 4 loop pressurized water reactors and Combustion Engineering designed pressurized water reactors for small break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2328PA, Revision 0 and EMF-2328PA Revision 0, Supplement 1PA Revision 0.

The S-RELAP5 PWR Small Break LOCA Evaluation Model consists of two primary computer codes:

(1) S-RELAP5 to compute the system and hot channel response, and
(2) RODEX2 to determine the rod conditions at the start of the transient.

There were two evaluation model error corrections made during the reporting period.

M5® LOCA Swelling and Rupture Model (SRM) Update

The M5® fuel clad swelling and rupture model (SRM) is used in several of the Framatome LOCA methodologies. The SRM was approved by the NRC in the early 2000s as part of the M5® Licensing Topical Report, BAW-10227PA, Rev. 1. Additional M5® cladding rupture test data has been obtained since the model's approval. Upon review of the data and the SRM's use in LOCA analyses, it was determined that certain aspects of the model would be impacted. Following the same approach as the original model, an updated M5® SRM was developed to take into account the updated test database. The model changes do not change the predicted occurrence or conditions at the time of rupture, but would impact the post-rupture cladding characteristics for certain rupture temperatures.

Each plant with an analysis of record (AOR) which was performed with a LOCA methodology using the M5® SRM was screened relative to the predicted rupture temperature. If the AOR had rupture temperatures less than the range of the model changes, the post-rupture conditions and, therefore, transient results would not change.

For this update, a 0ºF peak clad temperature (PCT) estimate was assigned for all plant types.

Error in the S-RELAP5 Oxidation Calculations

The condition report identified an error in the S-RELAP5 calculations of oxidation due to high temperature metal-water reaction. In a LOCA event, the cladding can swell (and potentially rupture) due to the difference in pressure between the fuel and the system which causes the clad to thin. The clad radius increases, while the thickness decreases. It was discovered that the S-RELAP5 oxidation calculations used cold cladding dimensions and therefore, did not fully account for the swelling phenomena. The error can lead to an under-prediction of the oxidation and heat from the metal-water reaction.

Only licensing bases supported by S-RELAP5 analyses which model clad swelling are impacted. The licensing basis analyses, inclusive of previous ΔPCT estimates, were evaluated and a ΔPCT estimate has been determined specifically for each plant. Supporting analyses were performed as necessary and the range of the impact is shown in the table below.

Plant Type	**10 CFR 50.46 Reportable Impact, °F**
W 4 Loop	0
W 3 Loop	0 to +14
CE 2x4 Loop	+2 to +57

Realistic PWR Large Break LOCA Model (EMF-2103PA Revision 3)

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering 2x4 designed pressurized water reactors for large break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2103PA, Revision 3.

The Realistic PWR Large Break LOCA Model consists of three primary computer codes:

(1) S-RELAP5 to compute the system and hot channel response,
(2) RODEX3A to determine the rod conditions at the start of the transient, and
(3) ICECON to determine the containment conditions.

There were three evaluation model error corrections made during the reporting period.

Inconsistency in the Placement of the Form Loss Coefficient in the Hot Leg in AUTOR5BASE_REV3 Generated Input Decks

During the training process for EMF-2103PA Revision 3, an inconsistency was identified related to the placement of the form loss coefficient in the hot leg in the plant models. Page A-32 of EMF-2103PA Revision 3 provides guidance on the location of the form loss coefficients for the hot leg piping model. The models built for the Realistic Large Break LOCA analysis using EMF-2103PA Revision 3 have the form loss coefficient placed in the incorrect location for the hot leg piping model.

The investigation of this issue was conducted by re-calculating the transient responses for various cases from the Analysis of Record, including blowdown cases and late reflood cases. The estimated impact of this change for the application of the RLBLOCA model calculated peak cladding temperature is 0°F.

Plant Type	**10 CFR 50.46 Reportable Impact, °F**
W 4 Loop	No plants using this methodology
W 3 Loop	No plants using this methodology
CE 2x4 Loop	0

M5® LOCA Swelling and Rupture Model (SRM) Update

The M5® fuel clad swelling and rupture model (SRM) is used in several of the Framatome LOCA methodologies. The SRM was approved by the NRC in the early 2000s as part of the M5® Licensing Topical Report, BAW-10227PA, Rev. 1. Additional M5® cladding rupture test data has been obtained since the model's approval. Upon review of the data and the SRM's use in LOCA analyses, it was determined that certain of aspects of the model would be impacted. Following the same approach as the original model, an updated M5® SRM was developed to take into account the updated test database. The model changes do not change the predicted occurrence or conditions at the time of rupture, but would impact the post-rupture cladding characteristics for certain rupture temperatures.

Each plant with an analysis of record (AOR) which was performed with a LOCA methodology using the M5® SRM was screened relative to the predicted rupture temperature. If the AOR had rupture temperatures less than the range of the model changes, the post-rupture conditions and, therefore, transient results would not change. For this update, a 0ºF peak clad temperature (PCT) estimate was assigned. Supporting analyses were performed as necessary and the range of the impact is shown in the table below.

Plant Type	**10 CFR 50.46 Reportable Impact, °F**
W 4 Loop	No plants using this methodology
W 3 Loop	No plants using this methodology
CE 2x4 Loop	0

Error in the S-RELAP5 Oxidation Calculations

The condition report identified an error in the S-RELAP5 calculations of oxidation due to high temperature metal-water reaction. In a LOCA event, the cladding can swell (and potentially rupture) due to the difference in pressure between the fuel and the system which causes the clad to thin. The clad radius increases, while the thickness decreases. It was discovered that the S-RELAP5 oxidation calculations used cold cladding dimensions and therefore, did not fully account for the swelling phenomena. The error can lead to an under-prediction of the oxidation and heat from the metal-water reaction.

Only licensing bases supported by S-RELAP5 analyses which model clad swelling are impacted. The licensing basis analyses, inclusive of previous ΔPCT estimates, were evaluated and a ΔPCT estimate has been determined specifically for each plant. Supporting analyses were performed as necessary and the range of the impact is shown in the table below.

Plant Type	**10 CFR 50.46 Reportable Impact, °F**
W 4 Loop	No plants using this methodology
W 3 Loop	No plants using this methodology
CE 2x4 Loop	0

Realistic PWR Large Break LOCA Model (EMF-2103PA Revision 0)

This model is applicable to Westinghouse designed 3 and 4 loop pressurized water reactors and Combustion Engineering 2x4 designed pressurized water reactors for large break LOCA analyses. The NRC approved topical report for this evaluation model is EMF-2103PA, Revision 0.

The Realistic PWR Large Break LOCA Model consists of three primary computer codes:

(1) S-RELAP5 to compute the system and hot channel response,
(2) RODEX3A to determine the rod conditions at the start of the transient, and
(3) ICECON to determine the containment conditions.

The three condition reports listed for EMF-2103PA Revision 3 above do not apply to EMF-2103PA Revision 0 since the methodology does not apply the same noding diagrams and does not model clad swelling and rupture.

Certain plant-specific applications with deviations from the method which were impacted by CR2017-3565 described above were evaluated and determined to have PCT impacts of 0 ºF.

Certain plant-specific applications with deviations from the method which were impacted by CR2017-5630 described above were evaluated and determined to have PCT impacts ranging from +22 ºF to +61 ºF.