AREVA

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

2014 - Annual Reporting of Changes and Errors in Emergency Core Cooling Systems (ECCS) Evaluation Models

Ref. 1: Letter, Pedro Salas (AREVA Inc.) to Document Control Desk (NRC), "2013 - Annual Reporting of Changes and Errors in Emergency Core Cooling Systems (ECCS) Evaluation Models," NRC:14:003, January 16, 2014.

Attached is a summary report of changes and error corrections implemented in the AREVA Inc. (AREVA) Emergency Core Cooling Systems (ECCSs) evaluation models for the period of January 1, 2014 to December 31, 2014. Reference 1 provided reporting for the previous year.

AREVA 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 AREVA 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@areva.com

Sincerely,

Pedro Salas, Director
Licensing & Regulatory Affairs
AREVA Inc.

cc: J. G. Rowley
Project 728

Attachments:

1. Attachment A- Listing of AREVA LOCA Evaluation Models
2. Attachment B- Annual Reporting of AREVA LOCA Evaluation Model Changes and Error Corrections (January 1, 2014- December 31, 2014)

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Attachment A

Listing of AREVA 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.

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 report for this evaluation model is EMF-2103PA, Revision 0.

Attachment B

Annual Reporting of AREVA LOCA Evaluation Model Changes and Error Corrections

(January 1, 2014- December 31, 2014)

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.

1. Implementation of the ACE Correlations in the RELAX Code
   The BWR LOCA topical report EMF-2361(P)(A) describes using CHF correlations developed for specific AREVA fuel design applications. The ANFB correlation was the specific correlation that was implemented in the topical report. Outside the applicable range of the fuel specific correlation, the RELAX code used existing approved CHF correlations established from the previously approved LOCA methodology. At the boundaries of the fuel specific correlation, the topical described how the CHF was calculated based on interpolation between the fuel specific correlation and the existing correlation. The topical stated future CHF correlations would be implemented with a similar interpolation scheme. When the ACE CHF correlation was implemented in RELAX, the interpolation scheme was not used to smooth the transition between correlations.

   The PCT impact of implementing the interpolation scheme for the ACE correlation was a maximum of +2°F.

2. Error in Applying the Modified Approach
   AREVA developed a modified analysis approach to address NRC concerns on certain cooling phenomena in the EXEM BWR-2000 ECCS evaluation model during some LOCA events. The modified analysis approach was concluded to be more conservative and generally acceptable in the Letter T. McGinty (NRC) to P. Salas (AREVA) "Proposed Analysis Approach for its EXEM Boling Water Reactor (BWR)-2000 Emergency Core Cooling System (ECCS) Evaluation Model," July 5, 2012. An error in the computer coding of the modified analysis resulted in a condition where a comparison was done at a specific time step (N), but the corresponding calculation and action occurred at the following time step (N+1). In most cases, the difference in time steps would result in essentially no numerical difference; however, it was hypothesized that in a unique situation with a large gradient the error could produce a difference.

   The PCT impact of correcting the numerical scheme was 0°F.

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.

<u>CRAFT2 PWR Small Break LOCA Evaluation Model</u>

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.

<u>RELAP5/MOD2-B&W Once Through Steam Generator Large and Small Break LOCA Evaluation Model</u>
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.
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. 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 following evaluation model changes or error corrections were made during the reporting period:

1. Increased Volume Average Fuel Temperatures (VAFT) due to Thermal Conductivity Degradation (TCD)
   Studies performed using the GALILEO and COPERNIC2 fuel performance codes (which adequately model TCD) have shown that the current methodology, which utilizes the TACO3 and GDATCO codes (which do not adequately model TCD) under predicts the initial VAFT used for analyzing a LOCA. This under prediction in VAFT leads to a significant PCT increase in the large break LOCA analysis.

   Based on the new LBLOCA initialization studies, it is concluded that the LOCA EM that uses TACO3 and GDTACO must be modified by application of additional fuel temperature uncertainty to account for the effects of TCD. To quantify the estimated impact of this issue, an evaluation was performed increasing the fuel temperature uncertainty to a Lowered-Loop (LL) LBLOCA plant model at middle-of-life burnup conditions. The results of the evaluation found a significant estimated PCT increase. The results of the evaluation were applied to all other B&W plants, and in all cases led to an estimated PCT above the 2200°F 10 CFR 50.46 criterion. As the PCTs exceeded 2200°F, a 10 CFR Part 21 notification was made to the NRC and the B&W Licensees.

   To ensure that the operating plants would not exceed 2200°F, prudent compensatory linear heat rate reductions were recommended to and implemented in all of the B&W plants. The estimated PCTs have been reported to each B&W plant licensee via 10 CFR 50.46 reporting letters. Details for how the evaluation model will be utilized moving forward are still in discussion.

Plant	10 CFR 50.46 Reportable Impact, °F
ANO-1	+388
DB-1	+394
ONS-1, 2 & 3	+428
TMI-1	+393

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.

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

(1) RELAP5/MOD2-B&W to compute the system, core and hot rod response during blowdown,
(2) REFLOD3B to calculate the time for refill of the lower plenum and core reflood rate, and
(3) 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 one code:

(1) RELAP5/MOD2 B&W to compute the system, core and hot rod response during the transient. A NRC-approved fuel code (currently TAC03 or GDTACO) is used to supply the fuel rod steady state conditions at the beginning of the small or large LOCA transient.

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

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.

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.

The following evaluation model changes or error corrections were made during the reporting period:

1. S-RELAP5 Vapor Absorptivity Correlation Correction
   The vapor absorptivity correlation applied to the S-RELAP5 based methodologies is provided in the S-RELAP5 Models and Correlation Code Manual. The equation used for the absorption coefficient of vapor contains the term of the pressure that needs to be truncated to obtain the correct emissivity values for an optically thick steam. No lower pressure limit on the vapor absorptivity correlation is required as the correlation is developed for optically thin gases, which already applies at low pressures.

   Results show that limiting the vapor absorptivity correlation to within its intended pressure range allows S-RELAP5 to predict the wall temperatures for THTF within the uncertainty bands or above the uncertainty bands (conservative).

   The coding correction for the Vapor Absorptivity correlation has been incorporated into the S-RELAP5 code. The following table shows the PCT impact for all plants that are using or may use their current SBLOCA analysis. The impact is shown as a range of temperatures that represents the bounding variations achieved with plant specific applications.

Plant Type	10 CFR 50.46 Reportable Impact, °F
W 4 Loop	+11
W 3 Loop	+17 to +45
CE 2x4 Loop	+23 to +90

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 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 following evaluation model changes or error corrections were made during the reporting period:

1. S-RELAP5 Vapor Absorptivity Correlation Correction
   The vapor absorptivity correlation applied to the S-RELAP5 based methodologies is provided in the S-RELAP5 Models and Correlation Code Manual. The equation used for the absorption coefficient of vapor contains the term of the pressure that needs to be truncated to obtain the correct emissivity values for an optically thick steam. No lower pressure limit on the vapor absorptivity correlation is required as the correlation is developed for optically thin gases, which already applies at low pressures.

   Results show that limiting the vapor absorptivity correlation to within its intended pressure range allows S-RELAP5 to predict the wall temperatures for THTF within the uncertainty bands or above the uncertainty bands (conservative).

   For Realistic Large Break LOCA (RLBLOCA), single phase steam only exists for a very limited time just before the beginning of reflood. During the majority of the blowdown phase and during the entire reflood phase, which are the important RLBLOCA phases, the core is in a dispersed flow regime. The S-RELAP5 methodology uses the FLECHT-SEASET reflood tests to determine the heat transfer bias and uncertainty under these conditions. In addition, the transient progression is very quick and the system depressurizes in the first few seconds after the break opening. Because of the fast depressurization, the amount of time that the correlation for vapor absorptivity used in RLBLOCA is applied outside of the range of applicability is limited. The impact of this change on calculated peak cladding temperature is 0°F.

2. Non-physical axial shapes generated by the modal decomposition procedure in RLBLOCA Rev.0 and Rev.0 Transition Package.
   In RLBLOCA, the axial shapes for the calculations are selected from many possible shapes from a large number of PRISM depletion. These shapes are dependent on the time in cycle and cover both top and bottom peaked shapes, within a range of Axial Offsets and a corresponding range of Fz values. The mapping procedure currently used is called "modal decomposition" and it uses a set of orthogonal sine functions to perform the mapping.

   A recent evaluation of the modal decomposition method led to a detailed examination of the actual axial shapes that were produced by the modal decomposition procedure. Some shapes exhibit a super-imposed oscillation created by the modal decomposition that leads to non-physical artificial local peaks and valleys in the shape.

In the evaluation performed, the modal decomposition method is compared to the linear interpolation method (developed for EMF-2103 Rev.3) for the mapped axial shapes to quantify the variation between the two methods and the original input axial shapes. In general, the evaluation of the modal decomposition method led to the conclusion that in future application of EMF-2103 Rev.0 and EMF-2103 Rev.0+ Transition Package, the modal decomposition method will not be used and a linear interpolation will be used for the mapping. The linear interpolation provides a significantly better fit for the axial shapes. The impact of this change on calculated peak cladding temperature is 0°F.