AREVA

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Additional Information Regarding the Review of EMF-2103P Revision 1, "Realistic Large Break LOCA Methodology for Pressurized Water Reactors"

Ref. 1: Letter, James F. Mallay (FANP) to Document Control Desk (NRC), "Request for Review and Approval of EMF-2103(P) Revision 1, 'Realistic Large Break LOCA Methodology for Pressurized Water Reactors'," NRC:04:027, August 9, 2004.

Ref. 2: Letter, Ronnie L. Gardner (AREVA NP) to Document Control Desk (NRC), "Request for Additional Information – EMF-2103P Revision 1, 'Realistic Large Break LOCA Methodology for Pressurized Water Reactors'," NRC:06:034, September 29, 2006.

AREVA NP Inc. (AREVA NP) requested the NRC's review and approval of the topical report EMF-2103(P) Revision 1, "Realistic Large Break LOCA Methodology for Pressurized Water Reactors" in Reference 1. The purpose of this letter is to document a revision to the methodology based on the NRC's review of Reference 1.

A meeting was held with the NRC on November 8, 2006 to discuss a revised statistical approach to demonstrate compliance with the criteria in 10 CFR 50.46 to be used with the Reference 1 topical report. The revised approached was described in the Reference 2 letter. The changes to be made to the currently approved topical report, EMF-2103PA Revision 0, to implement this revised approach are presented in Attachment A to this letter. The attachment presents the pages to be changed, with the changes shaded to make their identification easier. The pages which will be renumbered due to deletions, along with those that have no revised or additional text, are not shown.

The issuance of the approved topical report EMF-2103PA Revision 1 will include the revised pages shown in Attachment A. The original pages which are changed, other than due to renumbering, will be included in a separate section at the end of the topical report.

AREVA NP considers some of the information in the attachments to this letter to be proprietary. The affidavit provided with the original submittal of this topical report satisfies the requirements of 10 CFR 2.390(b) to support the withholding of the proprietary information from public disclosure.

Sincerely,

Ronnie L. Gardner

Ronnie L. Gardner, Manager
Site Operations and Regulatory Affairs
AREVA NP Inc.

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AREVA NP INC.
An AREVA and Siemens company

3315 Old Forest Road, P.O. Box 10935 Lynchburg, VA 24506-0935
Tel.: 434 832 3000 - Fax: 434 832 3840 - www.areva.com

cc: H. D. Cruz
J. H. Thompson
Project 728

Attachment B

Revisions to
EMF-2103NPA Revision 0

For Statistical Approach

the realistic LBLOCA event. Actual NPP operating conditions and typical technical specifications were assessed to identify allowed operating conditions. Sensitivity studies were performed using the selected NPP model to determine those parameters that impact the realistic LBLOCA event. For the most important parameters additional plant data were obtained, where available, so that actual operational data distributions could be determined.

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] The identification of the parameters and the results of the parameter studies are provided in Tables 5.1-5.4 and Section 5.1.

The methodology for determination of the combined biases and uncertainties and the development of a final statement of probability for the limiting criteria are addressed in Section 5.2. To perform these last two CSAU steps, [

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A licensing analysis for a 3-loop (W) designed plant is provided in Reference 16. Section 5.4 provides the final statement of overall conformance to the licensing criteria.

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An acceptance sampling approach will be used to demonstrate compliance to three of the criteria in 10 CFR 50.46(b) : peak cladding temperature, peak nodal oxidation, and total oxidation. The acceptance sampling approach is described in Reference 66, Chapter 21, "Quality Assurance through the 95/95 acceptance criterion," and in References 67 and 68. This approach is consistent with the regulation 10 CFR 50.46 which requires that it be shown with a high probability that none of the criteria in paragraph 50.46(b) will be exceeded.

The proposed approach directly demonstrates that the three criteria are satisfied simultaneously. The process samples from the population of LOCA transients for a specific plant and asks the question for each sample (LOCA transient): are the three criteria met? The answer to the question is either yes or no. Chapter 21 of Reference 66 demonstrates that if, in a set of 59 cases, all of the answers are yes, that there is 95% probability that at least 95% of the population (LOCA transients for a given plant) meet the three criteria. This complies with the regulatory requirement to show a high probability of meeting the criteria. The equation for the binomial density function on page 17-7 in Reference 66 can be used to define the number of cases that must meet the criteria to support the probability statement for larger numbers of cases. For example in a set of 260 cases there can be no more than seven no answers to still meet the probability statement.

5.2.2 Application of Methodology

The AREVA NP RLBLOCA methodology is a statistics-based methodology; therefore, the application does not involve the evaluation of different deterministic calculations. [

] The results of the cases run (peak cladding temperature, peak nodal oxidation and total oxidation) are compared to the limits for the three criteria in order to make the statement that there is 95% probability that at least 95% of the population (LOCA transients for a given plant) meet the three criteria.

Application of this methodology relies on two computer codes: RODEX3A and S-RELAP5. All key LBLOCA parameters are calculated from S-RELAP5; RODEX3A is used to generate the initial fuel properties to be used by the fuel performance models in S-RELAP5. Performance of the RLBLOCA calculations relies on three analyst-created code input files describing the fuel, plant thermal-hydraulics, and containment thermal-hydraulics. The fuel model input is processed by the RODEX3A code, which will produce a binary file describing fuel properties. This file will be processed by S-RELAP5 during the steady-state initialization. During steady-state initialization, S-RELAP5 will process only the RODEX3A binary output file and the steady-state plant model input. The LBLOCA calculation is an S-RELAP5 "Restart" calculation. It relies only on the steady-state restart file, the S-RELAP5 LBLOCA transient input file, and the containment model input. The containment model input is similar to the original ICECON code (Reference 14), which evolved from the CONTEMPT code (Reference 20). Reportable LBLOCA parameters can be retrieved from the S-RELAP5 transient output file. Figure 5.1 depicts the calculational framework.

The maximum values of the peak cladding temperature, peak nodal oxidation, and total oxidation will be reported for the cases that demonstrate that there is 95% probability that at least 95% of the population meet the three criteria. No statistical statement will be made with respect to the percentage of the population (LOCA transients for a given plant) that is bounded by these reported values.

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5.3 *Determination of combined Bias and Uncertainty (CSAU Step 13)*

This section presents the results of a sample RLBLOCA analysis for a W 4-loop plant. An actual licensing analysis is in progress for a W 3-loop plant and will be submitted by the utility following the utilities review and acceptance of the analysis (Reference 16).

This 4-loop sample problem was performed in accordance with the calculation framework shown in Figure 5.1 as described above and in more detail in Reference 13. The base input models for the fuel rod and NPP were developed as described above and in conformance with Reference 12. The input for the fuel rod code was developed based on an existing AREVA NP 17x17 fuel assembly with 0.955 cm (0.376 in) fuel rods. The input for the NPP was developed based on information which was obtained for several different 3 and 4-loop plants and consequently can only be considered as representative of a 4-loop plant. However, the NPP input model is adequate to demonstrate the application of the FRA-ANP RLBLOCA methodology described in this report.

The parameters treated statistically are listed in Table 5.5 and the values for the specific parameters and ranges addressed are given in Table 5.6. The distributions assumed for this sample problem are those given in Table 5.4. [

] The results of these calculations are presented in Figures 5.2 through 5.28.

Figures 5.2 through 5.16 present scatter plots for the more important phenomena/parameters in the analysis. These scatter plots are provided to demonstrate that the methodology does select input which covers the phenomena/parameter ranges and associated distributions. In general, it is difficult to see the PCT dependence of an individual parameter from these scatter plots. This is primarily due to the fact that there are several major parameters and a conservative combination of these parameters is required to obtain the higher values of PCT. Based on this the following paragraphs will concentrate on a discussion of the LBLOCA criteria as addressed by the analysis.

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5.4 *Determination of Total Uncertainty (CSAU Step 14)*

The biases and uncertainties determined during the code assessments are either directly addressed in the statistical analysis or demonstrated to be a code conservatism that adds an un-quantified conservatism to the reported results. The final results for the 4-loop sample problem can be summarized as follows:

- In the set of 59 cases the three criteria were satisfied in all cases. Therefore, there is 95% probability that at least 95% of the population (LOCA transients for a given plant) meet the three criteria. This demonstrates that there is a high probability that none of the criteria (peak cladding temperature, peak nodal oxidation, and total oxidation) will be exceeded.
- The maximum peak cladding temperature calculated in the 59 cases was 1686 degrees F.
- The maximum peak nodal oxidation calculated in the 59 cases was 1.1%.
- The maximum total oxidation calculated in the 59 cases was 0.022%.

**Table 5.7 Summary of Major Parameters
Describing Limiting PCT Case (Case 22)**

Time (hrs)	5850
Core Power (MW)	3297
Core Peaking (FQ)	2.44
Radial Peak (Fdh)	1.8000
Axial Offset	-0.163
Local Peaking (Fl)	1.098
Break Type	DEGB
Break Size (ft^2)	3.72 (~90%)
Offsite Power Availability	No
Diesel Start (s)	40.0
Decay Heat Multiplier	0.968

Table 5.8 Summary of Limiting Results (all cases)

PCT	
Temperature	*1686 °F*
Time	*34 seconds*
Elevation	*9.4 ft*
Metal-Water Reaction	
% Oxidation Maximum	*1.1 %*
% Total Oxidation	*0.022 %*
Total Hydrogen	*0.5 lb*

62) "Upper Plenum Test Facility, Test No. 8 Cold/Hot Leg Flow Pattern Test Quick Look Report," U9 316/88/11, Siemens AG, Erlangen Germany, September 1988.

63) "Upper Plenum Test Facility, Test No. 8 Cold/Hot Leg Flow Pattern Test Experimental Data Report," U9 316/88/12, Siemens AG, Erlangen Germany, September 1988.

64) XN-75-27(A), "Exxon Nuclear Neutronic Design Methods for Pressurized Water Reactors," Exxon Nuclear Company

65) EMF-96-029(P)(A), Reactor Analysis System for PWRs, January 1997.

66) D. Lurie and R. H. Moore, "Applying Statistics," NUREG-1475, US Nuclear Regulatory Commission, 1994.

67) G. B. Wallis, W. T. Nutt, "Reply to: Comments on *Evaluation of nuclear safety from the outputs of computer codes in the presence of uncertainties*, by W. T. Nutt and G. B. Wallis," by Y. Orechwa," Reliability Engineering and System Safety Vol. 87, pp 137-145 (2005).

68) G. B. Wallis, "Evaluating the probability that the outputs of a computer code with random inputs will meet a set of evaluation criteria," Reliability Engineering and System Safety Vol. 91, pp 820-827 (2006).

The methods used in the application of S-RELAP5 to the large break LOCA are described in Reference D.1. A detailed assessment of this computer code was made through comparisons to experimental data. These assessments were used to develop quantitative estimates of the code's ability to predict key physical phenomena in a PWR large break LOCA. The final step of the best-estimate methodology is to combine all the uncertainties related to the code and plant parameters and estimate the PCT at 95% probability. The steps taken to derive the PCT uncertainty estimate are summarized below:

1. *Base Plant Input File Development*

First, base RODEX3A and S-RELAP5 input files for the plant (including the containment input file) are developed. Code input development guidelines are applied to ensure that the model nodalization is consistent with the model nodalization used in the code validation (Reference D.3).

2. *Sampled Case Development*

The non-parametric statistical approach requires that many "sampled" cases be created and processed. For every set of input created, each "key LOCA parameter" is randomly sampled over a range established through code uncertainty assessment or expected operating limits (provided by plant technical specifications or data). Those parameters considered "key LOCA parameters" are listed in Table D.3.1. This list includes both parameters related to LOCA phenomena (based on the PIRT provided in Reference D.1) and to plant operating parameters.

3. *Determination of Adequacy of ECCS*

The results of the cases run (peak cladding temperature, peak nodal oxidation and total oxidation) are compared to the limits for the three criteria in order to make the statement that there is 95% probability that at least 95% of the population (LOCA transients for a given plant) meet the three criteria. The maximum values of the peak cladding temperature, peak nodal oxidation, and total oxidation will be reported for the cases that demonstrate that there is 95% probability that at least 95% of the population meet the three criteria.

D.3.3 Plant Description and Summary of Analysis Parameters

The plant analysis presented in this appendix is a Westinghouse designed pressurized water reactor (PWR), which has three loops, each with a hot leg, a U-tube steam generator, and a cold leg with a RCP. The RCS also includes one pressurizer. The ECCS includes one accumulator/LPSI and one HPSI injection path per RCS loop. The HPSI and LPSI feed into common headers which are connected to the accumulator lines.

The S-RELAP5 model explicitly describes the RCS, reactor vessel, pressurizer, and ECCS back to the common LPSI header and accumulators. This model also describes the secondary-side steam generator that is instantaneously isolated (closed MSIV and feedwater trip) at the time of the break. A symmetric steam generator tube plugging level up to 10% per steam generator was assumed.

As described in the FRA-ANP RLBLOCA methodology, many parameters associated with LBLOCA phenomenological uncertainties and plant operation ranges are sampled. A summary of those parameters sampled is given in Table D.3.1. The LBLOCA phenomenological uncertainties are provided in Reference D.1. Values for process or operational parameters, including ranges of sampled process parameters, and fuel design parameters used in the analysis are given in Table D.3.2. Plant data is analyzed to develop uncertainties for the process parameters sampled in the analyses. Table D.3.3 presents a summary of the uncertainties used in the analyses. Two parameters (refueling water storage tank (RWST) temperature and diesel start time) are set at a conservative bounding values for all calculations. Where applicable, the sampled parameter ranges are based on technical specification limits. Plant data are used to define range boundaries for loop flow (high end) and containment temperature (low end).

D.3.4 Realistic Large Break LOCA Results

A set of fifty-nine calculations were performed sampling the parameters listed in Table D.3.1. The limiting PCT case (1853 °F) was number 41, which is characterized in Table D.2.1. The limiting results from all cases are presented in Table D.3.4. The limiting maximum oxidation is 1.49 % and the limiting total oxidation 0.045 %. The fraction of total hydrogen generated was not directly calculated; however, it is conservatively bounded by the calculated total percent oxidation which is well below the 1 percent limit.

Table D.3.4 Summary of Limiting Results (All Cases)

PCT		
	Temperature	1853 °F
	Time	87.3 seconds
	Elevation	~8.7 ft
Metal-Water Reaction		
	% Oxidation Maximum	1.49 %
	% Total Oxidation	0.045 %
	Total Hydrogen	0.78 lb

D.4 Conclusions

- In the set of 59 cases the three criteria were satisfied in all cases. Therefore, there is 95% probability that at least 95% of the population (LOCA transients for a given plant) meet the three criteria. This demonstrates that there is a high probability that none of the criteria (peak cladding temperature, peak nodal oxidation, and total oxidation) will be exceeded.

- The maximum peak cladding temperature calculated in the 59 cases was 1853 degrees F.

- The maximum peak nodal oxidation calculated in the 59 cases was 1.49%.

- The maximum total oxidation calculated in the 59 cases was 0.045%.

The analysis supports operation at a power level of 2300 MWt (plus 2% uncertainty), a steam generator tube plugging level of up to 10% in any generator, a total peaking factor (F_Q^T) of 2.62 and a nuclear enthalpy rise factor ($F_{\Delta H}$) of 1.80 with no axially-dependent power peaking limit. The analysis supports peak rod average exposures of up to 62,000 MWd/MTU corresponding to a maximum assembly burnup of 57,000 MWd/MTU.

D.5 References

D.1. EMF-2103(P) Revision 0, *Realistic Large Break LOCA Methodology*, Framatome ANP Richland, Inc., August 2001.

D.2. Technical Program Group, *Quantifying Reactor Safety Margins*, NUREG/CR-5249, EGG-2552, October 1989.

D.3. EMF-2058(P) Revision 1, *S-RELAP5 Realistic Large Break LOCA Analysis Guidelines*, Framatome ANP Richland, Inc., August 2001.