FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT (TR) BAW-10255(P), REVISION 2

"CYCLE-SPECIFIC DIVOM METHODOLOGY USING THE RAMONA5-FA CODE"

AREVA NP, INC. (AREVA)

PROJECT NO. 728

1.0 INTRODUCTION AND BACKGROUND

By letter dated January 30, 2006, Framatome ANP, now known as AREVA, submitted to the U.S. Nuclear Regulatory Commission (NRC) Topical Report (TR) BAW-10255(P), Revision 2, entitled "Cycle-Specific DIVOM [Delta CPR [critical power ratio] over Initial CPR Versus Oscillation Magnitude] Methodology using the RAMONA5-FA Code" (Reference 1), for review and approval. The purpose of this TR is to describe the AREVA methodology for the evaluation of the critical power response of the core to regional oscillations on a cycle-specific basis, and to present the methodology for generating DIVOM curves based on cycle-specific analysis with the boiling water reactor (BWR) transient system code, RAMONA5-FA. DIVOM correlates the loss in CPR in the hot channel, given a measured power oscillation amplitude in the oscillation power range monitor (OPRM). The DIVOM correlation is used in defining the OPRM amplitude scram setpoint for the detect and suppress (D&S) long term stability solution.

The NRC staff review includes the TR and responses (References 2, 3, and 13) to the NRC staff Request for Additional Information (RAI) (Reference 12). The NRC staff was assisted in its review by its consultant, Oak Ridge National Laboratory (ORNL), who wrote the referenced technical evaluation report (TER) (Reference 5). The NRC staff reviewed the ORNL TER and adopts the findings recommended, which provide a detailed evaluation of the TR.

2.0 REGULATORY EVALUATION

The TR provides a methodology for calculating the DIVOM curve, which is an integral part of the setpoint methodology for most D&S long term stability solutions. Since the DIVOM curve methodology is part of the setpoint methodology, the TR was developed to comply with the requirements of Criteria 10 and 12 in Part 50 of Title 10 of the *Code of Federal Regulations* (10 CFR), Appendix A, "General Design Criteria for Nuclear Power Plants."

Criterion 10, "Reactor design," 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."

Criterion 12, "Suppression of reactor power oscillations," requires that: "The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed."

To ensure compliance with Criteria 10 and 12 of 10 CFR Part 50, Appendix A, the NRC staff will confirm that a licensee performs plant-specific trip setpoint calculations using NRC-approved methodologies, as stated in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Chapters 4.4 and 15.9. The TR would support a licensee's application for a Technical Specification (TS) license amendment.

3.0 TECHNICAL EVALUATION

The TR describes the methodology proposed by AREVA which would support the licensing basis and reload applications for the cycle-specific DIVOM methodology. The DIVOM correlation is used to estimate the delta CPR, as a function of power oscillation amplitude, and is required to select the scram setpoint for D&S long term stability solution.

3.1. DIVOM Application Procedure

In principle, two DIVOM correlations are calculated for each reactor condition: the core-wide mode DIVOM and the regional-mode DIVOM. Under all circumstances, the regional DIVOM correlation slope is larger (i.e., more conservative) than the core-wide DIVOM because regional-mode oscillations are always accompanied by larger swings in hot channel flow. Therefore, only the regional-mode DIVOM is used to set scram setpoints for BWR Owners' Group (BWROG) Option III Long Term Stability Solution (Option III), Detect and Suppress Solution Confirmation Density (DSS-CD), or the Enhanced Option III Long Term Stability Solution (EO-III). To calculate the cycle-specific DIVOM correlation, RAMONA5-FA is used to simulate regional oscillations at several state points throughout that cycle. For each exposure time, a growing power oscillation is calculated, as illustrated in Figure 6.1 of the TR BAW-10255(P), Revision 2. The RAMONA5-FA output is parsed using AREVA's DIVOM plot code (DIVOMPLT) to determine the maximum power swing bundle and the maximum CPR swing in a bundle. The power and CPR amplitudes for each oscillation are plotted against each other, and a piece-wise linear function is plotted to define a region that bounds all oscillations. For most applications this piece-wise linear function is a single straight line that defines a single slope, which is known as the DIVOM slope. However, the BWROG methodology allows for a more general DIVOM curve, where the slope varies with oscillation amplitude. AREVA's methodology is consistent with the BWROG methodology, because it allows for a general DIVOM curve.

The AREVA DIVOM Methodology Application Procedure is described in detail in Section 7 of TR BAW-10255(P). It includes the following steps:

1. Definition of the state points to be analyzed. Exposure, control rod pattern, power, flow, subcooling, and xenon level, are specified.

2. MICROBURN-B2 runs for the selected state points to generate cross section and hydraulic data for input into RAMONA5-FA and STAIF (Reference 6) codes.

3. Frequency domain analysis using STAIF to gain insight into the stability of the state points. These results are used to revise state point selection or introduce input modifications. The STAIF calculations also identify the state point with the largest channel decay ratio which, if large, needs to be examined for single channel neutron uncoupled oscillations.

4. RAMONA5-FA runs producing growing regional oscillations. The transient should continue until:

a. hot channel oscillation magnitude (HCOM) exceeds a preset limit (suggested minimum of 0.4), or
b. the minimum critical power ratio (MCPR) is less than unity calculated, or
c. oscillations are no longer increasing (stable limit cycle reached).

5. State point or input data modifications, as needed, for the purpose of exciting the regional mode oscillations while damping the global mode.

6. Post-processing of RAMONA5-FA output with the DIVOMPLT code to generate and plot DIVOM points, which define the DIVOM curve by simple linear interpolation between the points.

7. Correction of DIVOM points, if applicable, in the case input biases were necessary to excite growing regional oscillations.

DIVOM correlations may become ill-conditioned (i.e., mathematically undefined) if a single channel becomes thermal-hydraulically unstable. Some Long Term Stability Solutions (e.g., Enhanced Option III), preclude by design single channel instabilities. Other D&S solutions may be susceptible to channel instability issues with the resulting ill-conditioned DIVOM correlations, which produce large DIVOM slope values. For these D&S solutions, the highest calculated DIVOM slope must be used. Alternatively, the target control rod patterns may be modified to preclude single channel instabilities.

3.2. RAMONA5-FA Code

RAMONA5-FA is the transient system code used for the AREVA DIVOM methodology. RAMONA5-FA is a complete 3-D transient system code, and is based on the Brookhaven National Laboratory RAMONA3 code (Reference 7), which was later modified by Studsvik-Scandpower to become RAMONA5 V2.4 (Reference 8). AREVA's RAMONA5-FA is based on the Studsvik version.

3.2.1. Description of the RAMONA5-FA Code

As with the earlier versions of the code, RAMONA5-FA uses a four equation, non-homogeneous, non-equilibrium, one dimensional, two-phase flow model. The four equations used describe:

1. the liquid mass conservation equation,
2. the vapor mass conservation equation,
3. the mixture non-equilibrium energy conservation equation, and
4. the integrated mixture momentum equation with drift flux.

The momentum equation is integrated through the vessel flow loop to predict the individual velocities for each vessel component and core channel inlet for each time step. The core model consists of parallel hydraulic channels allowing each individual fuel channel to be modeled separately.

3.2.2. Improvements to the AREVA Version of the RAMONA Code

AREVA's RAMONA5-FA code includes the following improvements:

1. The neutron cross section data and hydraulic core data are prepared automatically by coupling to the core simulator MICROBURN-B2. The differences in initial steady state power distribution have been eliminated by applying an adaptive 3D coupling method.

2. A new modal neutron kinetics module has been installed in RAMONA5-FA to allow better user control over the oscillation mode.

3. The fuel pin model in RAMONA5-FA was improved by incorporating models from the frequency domain stability code STAIF, including:

   a. fuel pellet conductivity dependence on temperature and exposure,
   b. detailed gap conductance model, and
   c. neutron self-shielding effects on power deposition distribution in pellets.

4. AREVA's hydraulic and dryout correlations have been installed.

These modifications are documented in Section 4 of the TR BAW-10255(P), and in the response to the NRC staff RAI. The most far-reaching modification is the inclusion of the option to use modal kinetics expansion to the 3D neutronic solver in RAMONA5-FA. When this option is selected, RAMONA5-FA solves the 3D neutronic equations based on an expansion in modes, which are calculated automatically from the power distributions of the steady-state from the steady-state core simulator (MICROBURN-B2). Modal kinetics expansion is similar to using the point kinetics approximation, which uses the first critical mode, but, in addition, RAMONA5-FA uses higher order modes.

3.3. Key Review Features

The DIVOM methodology is well established and has been approved by the NRC staff. Therefore, the key review questions are:

1. Do the proposed AREVA DIVOM calculation procedures comply with the approved methodology?

2. Is RAMONA5-FA qualified to model the growing unstable power oscillations that are required in the calculation procedures? The answer to this question includes an evaluation of the modifications to RAMONA5-FA, including the modal neutronics method.

3. Given a power oscillation, can RAMONA5-FA estimate the reduction in CPR?

The above key questions are addressed in the following three sections.

3.3.1. Compliance of AREVA's DIVOM Methodology with Approved Methods

AREVA's DIVOM methodology is described in Section 7 of TR BAW-10255(P), Revision 2, and additional details are provided in the response to the NRC staff's RAI. The key features of the methodology are described in Section 3.1 of this SE.

In Section 7 of the TR, AREVA states that: "A reduced scope of parameter variations can be considered on a case-by-case basis for subsequent reload analysis. The basis for any reduced scope should be justified and documented per Section 4.1 of the BWROG guideline. However, as the effort required to justify a reduced scope may exceed the effort of running a full analysis, reduced scope is not recommended." If a reduced scope of parameter variations is used to define the cycle-specific DIVOM slope, the scope must be justified and documented for NRC staff review. The NRC staff concludes that the AREVA procedure is consistent with the approved BWROG DIVOM methodology.

3.3.2. Qualification of the RAMONA5-FA Code

The NRC staff review of this TR is limited to the generation of DIVOM correlations, and is not a complete review of the RAMONA5-FA code for generic transient analyses. However, EFW operation (e.g., MELLLA+) poses additional challenges to the calculations; therefore, the NRC staff imposes a condition to perform a full code review of RAMONA5-FA, including constitutive relations, numerics, neutronic methods, and bechmarks before RAMONA5-FA can be used to calculate DIVOM curves in EFW operating domains. The NRC staff has initiated this review with available documents, but additional information will be required from AREVA to complete the review. Until the review is completed, AREVA must include an interim 10 percent penalty on the DIVOM slopes calculated by the RAMONA5-FA methodology in EFW domains. Once the NRC staff review is completed, this limitation will be removed.

In order to calculate DIVOM correlations, the RAMONA5-FA code should be capable of reliably generating self-consistent growing power oscillations and be capable of estimating the reduction in CPR margin during those oscillations. Strictly speaking, RAMONA5-FA is not required to estimate the value of the decay ratio (DR) accurately to determine DIVOM correlations, because the procedure allows for biasing and changes in operating conditions until a growing power oscillation develops. The only requirement is that those power oscillations be self-consistent (i.e., be accompanied by consistent flow and void oscillations). The accuracy of the computed frequency of oscillation is, therefore, more relevant to DIVOM results than the actual DR because the oscillation frequency affects directly the flow and void dynamics (mainly through the fuel-heat-capacity filtering effect).

Two DIVOM correlations are typically calculated: the core-wide and the regional DIVOM. The reduction in CPR during oscillations is controlled mostly by the amplitude of the flow/void oscillations instead of the amplitude of the power oscillations. Due to their nature, regional instabilities result in larger flow oscillations than core-wide instabilities, and the regional DIVOM slope is in all cases more steep than the core-wide DIVOM slope. In the physical situation, one has a closed-loop where the power oscillations drive the voids and the voids, in turn, feedback to the power. However, the void-to-power feedback is essentially instantaneous (the neutron generation time is a few micro seconds). The power-to-void feedback has about a 6 second time constant because of the fuel-heat-capacity filtering effect. Thus, a convenient first-approximation is to model that the voids oscillations are driving the power oscillations. In a core-wide oscillation, the voids induce reactivity changes, which induce power oscillations; however, in the regional case, the same reactivity change will result in a smaller power oscillation. Consequently, in DIVOM terms, for the same power oscillation amplitude, a subcritical mode (i.e., regional oscillations) will require a larger void oscillation and will reduce the CPR margin more than a critical mode (i.e., core-wide oscillations).

AREVA has qualified the RAMONA5-FA code for DR and frequency calculations against channel thermal hydraulic tests in the Karlstein Thermal Hydraulic (KATHY) facility and against real plant instability events. The instability events include both regional and core-wide, but incorporate more regional events, because they generate more conservative DIVOM slopes. The results of these benchmarks are given in Section 5.1 through 5.4 of Reference 1. The reactor events include:

1. CGS Cycle 8: - Global Instability,
2. GUNC Cycle 13: - Regional Instability,
3. GUNC Cycle 1: - Regional Instability, and
4. KKK Cycle 3: - Regional Instability.

In addition, RAMONA5-FA has been benchmarked against a number of KATHY flow loop stability measurements. These measurements are for purely thermal-hydraulic oscillations (no neutronics) and benchmark the channel DR capability of RAMONA5-FA. They also benchmark the capability of RAMONA5-FA to model self-consistent flow-void oscillations. The results are shown in Figure 5.1 and Figure 5.2 of Reference 1.

Even though the NRC staff has not yet conducted a full review of the RAMONA5-FA code, the NRC staff concludes that the RAMONA5-FA benchmarking against channel, core-wide, and regional oscillations is satisfactory. RAMONA5-FA has demonstrated the capability to generate self-consistent power-flow-void oscillations of the correct frequencies to be used for DIVOM calculations up to EPU conditions.

EFW operation (e.g., MELLLA+) poses additional challenges to the calculations, and the NRC staff has imposed a condition to perform a full code review of RAMONA5-FA, including constitutive relations, numerics, neutronic methods, and bechmarks before RAMONA5-FA can be used to calculate DIVOM curves in EFW operating domains. While the review is in progress, the NRC staff imposes a restriction to include an interim 10 percent penalty in DIVOM slopes calculated using the RAMONA5-FA methodology in EFW domains.

The NRC staff issued an RAI (Reference 12), requesting justification for the adequacy of the 10 percent penalty, and additional information on the performance of RAMONA5-FA CPR correlations under oscillatory conditions. This information was documented by AREVA in Reference 13. The NRC staff finds AREVA's evaluation of the adequacy of the interim 10 percent DIVOM penalty acceptable. The main points from this evaluation are:

1. AREVA has submitted additional information (Reference 13) regarding the CPR performance of the RAMONA5-FA methodology under oscillatory flow conditions. In addition to the ATRIUM-10 data presented in TR BAW-10255(P), Revision 2 (Reference 1), AREVA has documented:

    a. Additional test data for ATRIUM-9 fuel, and

    b. Additional processing of the ATRIUM-10 data that shows that the CPR violation onset calculated by RAMONA agrees with all the KATHY measured data when one standard deviation is added to the predicted CPR values.

2. A 10 percent DIVOM penalty is equivalent of a OLMCPR penalty of approximately 0.025. The NRC staff finds that this value is significant and likely to cover any deficiencies that may arise from the on-going full code review. This evaluation is based on the fact that even when using RAMONA5-FA as a "black box" (i.e., a non-fully-reviewed code):

   a. the decay ratios calculated agree remarkably well with a large number of benchmark cases, including channel stability (KATHY tests) , and both core-wide and regional stability modes in operating reactors (See example in Figure 1), and

   b. RAMONA5-FA predicts the onset of dryout conditions under the oscillatory conditions germane to DIVOM (See example in Figure 2). RAMONA5-FA predicts the onset of dryout conditions when the CPR becomes less than 1.0. In Figure 2, agreement is observed between the times for CPR<1 and measured temperature increases when a one-sigma error is accounted for.

Therefore, the NRC staff concludes that the interim 10 percent DIVOM penalty is likely to account for any possible code deficiencies that may arise from the full review of the RAMONA5-FA code.

3.3.3. Applicability of AREVA Dryout Correlation to Oscillatory Flow Conditions

The hydraulic loop at KATHY was used for several campaigns to measure the stability characteristics of new fuel types. In some of these experiments, the power was increased beyond the stability threshold, and resulted in growing flow rate oscillations. When the flow oscillations were allowed to grow to large magnitudes, some of the thermocouples attached to the inner surface of the electrically heated pins responded with elevated temperature that followed inlet flow minima by a time delay characteristic of the density wave, marking the arrival of the flow minimum to the elevation of the thermocouple. The temperature response is clearly indicative of degraded heat transfer or dryout conditions.

RAMONA5-FA was used to simulate these cyclic dryout and rewetting tests for an ATRIUM-10 electrically heated bundle with a bottom-skewed axial power shape. The measured oscillatory inlet flow rate is imposed as a boundary forcing function and the CPR response is calculated.

Some of these results are shown in Figure 3.1 of Reference 1. An excellent agreement is shown between the measured clad temperature increases and the times where the RAMONA5-FA predicts dryout (i.e., CPR < 1.0). This indicates the adequacy of using a steady state dryout correlation during oscillatory flow transients similar to those used by the DIVOM methodology.

AREVA compared the predictions of three different dryout correlations: ANFB-10, Siemens Power Corporation B (SPCB) correlation, and XL10A1. The results are shown in Figure 3.2 of Reference 1. These results indicate that all three dryout correlations that are currently programmed in RAMONA5-FA respond similarly to flow oscillations, and all three predict the inception of dryout conditions. Section 3.2 of Reference 1 performs additional benchmarks and sensitivity studies. The NRC staff concludes that the RAMONA5-FA code can correctly predict the onset of dryout conditions during power oscillations representative of instabilities, which are used in the methodology to calculate the DIVOM correlation.

In AREVA's response to the NRC staff RAI (Reference 13), AREVA provided additional information on ATRIUM-9 oscillatory-flow dryout tests. It also provided a statistical analysis of the RAMONA5-FA calculations to demonstrate that the RAMONA5-FA predictions agree with the measured dryout times when a one-sigma error is added to the calculation (Figure 2). AREVA also provided a physical explanation for the observed reduction in fuel temperature approximately 10 seconds before the CPR occurred. **[**

] The NRC staff concurs with AREVA's evaluation and concludes that the RAMONA5-FA methodology can predict the onset of dryout conditions under flow oscillations characteristic of a density-wave instability.

3.4. Treatment of Uncertainties

In Section 3.4 of Reference 1, AREVA presents the results of a phenomena identification and ranking table (PIRT). All of the high and medium ranking phenomena are addressed either by the DIVOM procedure or captured by plant-specific data. Table 3.1 of the TR documents these evaluations.

Section 6 of the TR contains a detailed sensitivity analysis of DIVOM results to high ranking parameters. The results of the analysis are summarized in Table 6.2 of the TR. As expected, the largest sensitivity is the mode of oscillation. Changing the mode from regional to core-wide reduces the DIVOM slope by -0.115 (26 percent). The DIVOM procedure sets the oscillation mode to regional, which is conservative.

The second largest sensitivity is to the eigenvalue separation between core-wide and regional modes, which could affect the DIVOM slope by as much as 20 percent. The RAMONA5-FA code calculates the eigenvalue separation from first principles, and errors in Eigen value separation are expected to be significantly smaller than the values assumed in the sensitivity analyses.

Among the thermal-hydraulic parameters, AREVA has observed sensitivities as high as 19 percent to void-quality correlation in the conservative direction. The sensitivity analyses indicate that the RAMONA5-FA code uses the void-quality correlation that results in the most conservative DIVOM slope. The only non-conservative sensitivity is related to the gap conductance, which could be as high as 10 percent if the gap is misestimated by 50 percent. Since gap conductance is treated in the RAMONA5-FA code with best-estimate modern methods, a 50 percent error is unlikely. The expected error on the DIVOM slope, if the gap conductance was misestimated, is a few percent, and the DIVOM slope could be conservative if the gap conductance is over-estimated. The NRC staff concludes that, based on the sensitivity results provided, the AREVA DIVOM procedure sets most parameters (except for possibly gap conductance) at conservative values.

4.0 <u>LIMITATIONS AND CONDITIONS</u>

The NRC staff has reviewed TR BAW-10255(P), Revision 2, "Cycle Specific DIVOM Methodology using the RAMONA5-FA Code," and the responses to the NRC staff's RAI to determine the acceptability of the TR. The NRC staff concludes that the TR is acceptable with conditions and limitations described as follows:

1. If a reduced scope of parameter variations is used to define the cycle-specific DIVOM slope as described in Section 7 of the TR, the scope must be justified and documented for NRC staff review.

2. The NRC staff imposes a condition to perform a full code review of RAMONA5-FA, including constitutive relations, numerics, neutronic methods, and bechmarks before RAMONA5-FA can be used to calculate DIVOM curves in EFW operating domains without the 10 percent penalty on DIVOM slopes, as noted in Limitation and Condition No. 3 below.

3. The NRC staff imposes an interim 10 percent penalty on DIVOM slopes calculated using the RAMONA5-FA methodology under EFW conditions. This is an interim restriction that will be revised when the full RAMONA5-FA Code review is completed.

5.0 CONCLUSION

The NRC staff has reviewed TR BAW-10255(P), Revision 2, "Cycle-Specific DIVOM Methodology using the RAMONA5-FA Code," and the responses to the NRC staff's RAI. The AREVA methods and procedures documented in the TR, and as supplemented by the responses to NRC staff's RAI, represent a technically acceptable methodology to calculate DIVOM slope values. These methods and procedures define the AREVA DIVOM Methodology. The NRC staff concludes that the AREVA DIVOM Methodology is consistent with the previously approved BWROG methodology for calculating generic DIVOM slope values. The slope values calculated by the AREVA DIVOM Methodology are applicable to any D&S long term stability solution methodology that requires a setpoint calculation to suppress power oscillation before specified acceptable fuel design limits are compromised.

The RAMONA5-FA code is an integral part of the AREVA DIVOM Methodology. Based on the benchmarking and description provided in the TR, the NRC staff concludes that the RAMONA5-FA code is capable of:

a. computing self-consistent power oscillations of a frequency representative of unstable power oscillations, and

b. estimating the loss of CPR induced by these oscillations.

The NRC staff concludes that the TR is acceptable for referencing in licensing applications for BWRs, for which an operating license was issued under 10 CFR Part 50 prior to the date of this letter, to the extent specified and under the Limitations and Conditions delineated in Section 4.0 of this Safety Evaluation.

6.0 REFERENCES

1. TR BAW-10255(P) Revision 2, "Cycle-Specific DIVOM Methodology using the RAMONA5-FA Code," January 30, 2006, ADAMS Accession No. ML060330502.

2. R. L. Gardner, AREVA letter to Document Control Desk, NRC, "Response to a Request for Additional Information Regarding BAW-10255(P) Revision 2, "Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code," August 10, 2007, ADAMS Accession No. ML072290190.

3. R. L. Gardner, AREVA letter to Document Control Desk, NRC, “Response to a Request for Additional Information BAW-10255(P) Revision 2, ”Cycle-Specific DIVOM Methodology Using RAMONA5-FA Code,” October 2007.

4. H. D. Cruz, NRC letter to R. L. Gardner, AREVA, “Request for Additional Information RE: AREVA NP, Inc. Topical Report (TR) BAW-10255(P), Revision 2, “Cycle-Specific DIVOM Methodology using RAMONA5-FA Code” (TAC No. MC9767),” July 19, 2007, ADAMS Accession No. ML071790166.

5. ORNL TER, Review of AREVA BAW-10255(P) Revision 2, "Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code," October 2007, ADAMS Accession No. ML073120285.

6. EMF-CC-074(P)(A) Volumes 1 through 4, STAIF A Computer Program for BWR Stability Analysis in the Frequency Domain, Siemens Power Corporation, 1993 (Volume 1) through 2000 (Volume 4).

7. NUREG/CR-3664, W. Wulff, H. S. Cheng, D. J. Diamond, and M. Khatib-Rahbar, “A Description and Assessment of RAMONA-3B MOD.0 CYCLE 4: A Computer Code with Three-Dimensional Neutron Kinetics for BWR System Transients,” 1984.

8. RAMONA5 Version 2.4, “Users and Theory Manuals,” Studsvik-Scandpower.

9. NEDO-31960-A, BWR Owners’ Group Long-Term Stability Solutions Licensing Methodology, November 1995.

10. NEDO-31960-A, Supplement 1, BWR Owners’ Group Long-Term Stability Solutions Licensing Methodology, November 1995.

11. NEDO-32465-A, BWR Owners’ Group Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications, August 1996.

12. H. D. Cruz, NRC letter to R. L. Gardner, AREVA, “Request for Additional Information Re: U.S. Nuclear Regulatory Commission (NRC) Advisory Committee on Reactor Safeguards (ACRS) Review of Draft Safety Evaluations for AREVA NP Inc. (AREVA) Topical Report (TR) ANP-10262(P), Revision 0, (TAC No. MC9766) and AREVA TR BAW-10255(P), Revision 2, (TAC No. MC9767),” January 29, 2008, ADAMS Accession No. ML080250416.

13. R. L. Gardner, AREVA letter to Document Control Desk, NRC, “Response to a Request for Additional Information Regarding BAW-10255(P) Revision 2, ‘Cycle-Specific DIVOM Methodology using the RAMONA5-FA Code,’” April 4, 2008, ADAMS Accession No. ML080990061.

Attachments: 1. Figures 1 and 2
2. Resolution of Comments

Principal Contributor: Tai Huang

Date: May 21, 2008

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Figure 1. Comparison of channel decay ratio predictions by RAMONA5-FA against KATHY facility measurements

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Figure 2. Comparison of CPR predicted by RAMONA5-FA and rod temperatrure measurements for Atrium-10 fuel

RESOLUTION OF RESPONSES TO ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS) GENERATED REQUEST FOR ADDITIONAL INFORMATION QUESTIONS

DRAFT SAFETY EVALUATION FOR AREVA NP, INC. (AREVA)

TOPICAL REPORT (TR) BAW-10255(P), REVISION 2

“CYCLE-SPECIFIC DIVOM METHODOLOGY USING THE RAMONA5-FA CODE“

On November 15, 2007, the U.S. Nuclear Regulatory Commission (NRC) ACRS convened to review TR BAW-10255(P), Revision 2, and its associated draft SE. As a result, a revised NRC draft SE regarding NRC approval of TR ANP-10255, Revision 0, was issued on December 3, 2007 (ADAMS Accession No. ML073331078). The ACRS again convened on December 6, 2007, to review TR BAW-10255(P), Revision 2, and its associated revised draft SE. By letter dated December 27, 2007 (ADAMS Accession No. ML073440135), the ACRS provided its conclusions and recommendations. As a result of the ACRS review, and subsequent NRC staff discussions, the NRC staff requested additional information on January 29, 2009 (ADAMS Accession No. ML080250416). By letters dated February 8, 2008, March 4, 2008, and April 4, 2008 (ADAMS Accession Nos. ML080440086, ML080660123, and ML080990061, respectively), AREVA provided responses to the NRC staff RAI resulting from the ACRS review of the revised draft SE. The following is the NRC staff’s resolution of the RAI responses.

LOCATION	CHANGE TO THE SE
Page 1, Lines 15 and 16	Addition of References 12, and 13
Page 5, Line 1	Addition of the following sentence: “The above key questions are addressed in the following three sections.”
Page 5, Line 19	In response to the ACRS Conclusion and Recommendation Nos. 5 and 6, the paragraph was modified, as follows: “However, EFW operation (e.g., MELLLA+) poses additional challenges to the calculations; therefore, the NRC staff imposes a condition to perform a full code review of RAMONA5-FA, including constitutive relations, numerics, neutronic methods, and bechmarks before RAMONA5-FA can be used to calculate DIVOM curves in EFW operating domains. The NRC staff has initiated this review with available documents, but additional information will be required from AREVA to complete the review. Until the review is completed, AREVA must include an interim 10 percent penalty on the DIVOM slopes calculated by the RAMONA5-FA methodology in EFW domains. Once the NRC staff review is completed, this limitation will be removed.”

LOCATION	CHANGE TO THE SE
Page 6, Line 15	In response to the ACRS Conclusion and Recommendation No. 6, the paragraph was modified, as follows: "Even though the NRC staff has not yet conducted a full review of the RAMONA5-FA code…"
Page 6, Lines 20-35	In response to the ACRS Conclusion and Recommendation No. 6, the paragraphs included were modified, as noted in Section 3.3.2 of this Final SE.
Page 7, Line 18	In response to the ACRS Conclusion and Recommendation No. 5, the following paragraph was added: "In AREVA's response to NRC staff RAI (Reference 13), AREVA provided additional information on ATRIUM-9 oscillatory-flow dryout tests. It also provided a statistical analysis of the RAMONA5-FA calculations to demonstrate that the RAMONA5-FA predictions agree with the measured dryout times when a one-sigma error is added to the calculation (Figure 2). AREVA also provided a physical explanation for the observed reduction in fuel temperature approximately 10 seconds before the CPR occurred. **[** **]** The NRC staff concurs with AREVA's evaluation and concludes that the RAMONA5-FA methodology can predict the onset of dryout conditions under flow oscillations characteristic of a density-wave instability."
Section 4.0, Limitations and Conditions	In response to the ACRS Conclusion and Recommendation Nos. 5 and 6, Limitations and Conditions 2-4 were modified, as noted in Limitations and Conditions 2 and 3, in Section 4.0 of this Final SE.
Page 9, Line 46	Addition of References 12 and 13.