May 29, 2001

Mr. James F. Mallay
Director, Regulatory Affairs
Framatome ANP, Richland, Inc.
2101 Horn Rapids Road
Richland, WA 99352

SUBJECT: ACCEPTANCE FOR REFERENCING OF LICENSING TOPICAL REPORT EMF-2361(P), REVISION 0, "EXEM BWR-2000 ECCS EVALUATION MODEL" (TAC NO. MB0574)

Dear Mr. Mallay:

The NRC staff has completed its review of Topical Report EMF-2361(P), Revision 0, "EXEM BWR-2000 ECCS Evaluation Model" submitted by Framatome ANP Richland, Inc. (FRA-ANP, previously known as Siemens Power Corporation) on November 7, 2000, and supplemented by letters dated March 1, 2001, March 23, 2001, April 12, 2001, and May 2, 2001.

On the basis of our review, the staff finds the subject report to be acceptable for referencing in license applications to the extent specified, and under the limitations delineated in the report, and in the enclosed safety evaluation (SE). The SE defines the basis for NRC acceptance of the report.

Pursuant to 10 CFR 2.790, we have determined that the enclosed SE does not contain proprietary information. However, we will delay placing the SE in the public document room for a period of ten (10) working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects only. If you believe that any information in the enclosure is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.790.

The staff will not repeat its review and acceptance of the matters described in the report, when the report appears as a reference in license applications, except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with the procedures established in NUREG-0390, the NRC requests that FRA-ANP publish accepted versions of the report, including the safety evaluation, in the proprietary and non-proprietary forms within 3 months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted versions shall include an "-A" (designating accepted) following the report identification symbol. The accepted versions shall also incorporate all communications between FRA-ANP and the staff during this review.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are no longer valid, FRA-ANP and the licensees referencing the topical report will be expected to revise and resubmit their respective documentation, or to submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

Sincerely,

/RA by Robert A. Gramm for/

Stuart A. Richards, Director
Project Directorate IV and Decommissioning
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 702

Enclosure: Safety Evaluation

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are no longer valid, FRA-ANP and the licensees referencing the topical report will be expected to revise and resubmit their respective documentation, or to submit justification for the continued effective applicability of the topical report without revision of their respective documentation.

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Enclosure: Safety Evaluation

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TOPICAL REPORT EMF-2361(P), REVISION 0

"EXEM BWR-2000 ECCS EVALUATION MODEL"

PROJECT NO. 702

1.0 INTRODUCTION

Framatome ANP Richland Inc. (FRA-ANP), formerly known as Siemens Power Corporation (SPC), submitted Topical Report EMF-2361(P), Revision 0, "EXEM BWR-2000 ECCS Evaluation Model," (Reference 1), on November 7, 2000 (Reference 2), for NRC review and approval. FRA-ANP submitted additional information on March 1, 2001 (Reference 3), March 23, 2001 (Reference 4), April 12, 2001 (Reference 5), and May 2, 2001 (Reference 6). The report describes revisions made to the EXEM/BWR emergency core cooling system (ECCS) evaluation model. This upgraded model, called EXEM BWR-2000, continues to meet the requirements of 10 CFR Part 50 Appendix K. The revisions made to the EXEM/BWR methodology to create EXEM BWR-2000 include a number of changes. The primary modification was that the system blowdown code (RELAX) in the methodology was upgraded and the core reflood code (FLEX) was eliminated. The remainder of the codes and methodology are unchanged from the EXEM/BWR model.

The NRC Core Performance Inspection (Inspection Report 99900081/97-01) of FRA-ANP in 1997, included an assessment of the EXEM/BWR loss-of-coolant accident (LOCA) methodology. The applicant stated that one of the principal reasons for developing the EXEM BWR-2000 was to address several issues raised during this inspection and to address known deficiencies in the current methodology.

EXEM/BWR, which is the current NRC approved model, uses the FLEX code to compute the vessel refill and to define the time of core reflood. Although the use of the FLEX code saved computing time (when using mainframe computers), transferring the system calculation results from the RELAX system blowdown code to the FLEX system refill calculation required substantial data transfer and user intervention. With the aid of advanced computer workstations and the upgraded numeric installed in RELAX in 1991, the applicant proposed to replace the FLEX code by extending the RELAX blowdown calculation through the refill period to predict the time of core reflood. This change eliminates the FLEX code and removes the attendant data transfer between RELAX and FLEX and user intervention.

During the 1997 inspection, the NRC determined that the benchmarking and validation of the RELAX and FLEX codes needed to be improved. Three additional full integral simulation test (FIST) comparisons were incorporated into the modified version of RELAX validation test suite to more fully demonstrate its performance.

Code and application changes were implemented to improve the RELAX model performance for refill and reflood and to achieve consistency with current FRA-ANP fuel design tools. These changes include:

- Replacement of the Ishii drift flux model by extending the Ohkawa-Lahey correlation for the full range of void fractions.
- Inclusion of appropriate FRA-ANP critical heat flux (CHF) correlations for new FRA-ANP fuel designs.
- An upgrade of the two-phase pump degradation model based on Combustion Engineering - Electric Power Research Institute (CE-EPRI) data.
- Increased core, hot channel, and jet pump nodalization.
- Modification of other application options to improve code performance during refill and reflood including reflood criteria.
- An enthalpy injection model to ameliorate exaggerated condensation of subcooled core spray.

2.0 EVALUATION MODEL

In the topical report the applicant discusses the evaluation model, the proposed revisions, and assesses the proposed evaluation model.

2.1 Background

FRA-ANP's BWR LOCA methodology has evolved through four major model submittals as follows:

1. The evolution began with the non-jet pump (NJP) BWR fuel heatup model documented in XN-235(A) (Reference 7) and approved for limited use.

2. The water reactor evaluation model (WREM)-based NJP-BWR ECCS evaluation model is documented in XN-75-55(A) and Supplements 1 and 2 (Reference 8). This model introduced the RELAP4 system model calculation and remains approved for NJP-BWR applications.

3. The EXEM/BWR LOCA ECCS evaluation model upgraded the NJP models for jet pump BWR applications. This model is documented in XN-NF-80-19(P)(A) Volumes 2, 2A,

2B, and 2C (Reference 9). The RELAP4 model was modified to become the RELAX code and the FLEX code was introduced in this submittal.

4. The revised EXEM/BWR model is documented in ANF-91-048(P)(A) (Reference 10), while ANF-91-048(P)(A) Supplements 1 and 2 (Reference 11) document a change to the RELAX jet pump model. This revised EXEM/BWR model is the currently approved evaluation model.

The proposed LOCA evaluation model, EXEM BWR-2000 consists of a series of computer codes (RODEX2, RELAX, and HUXY) linked together to perform LOCA analyses to demonstrate plant and fuel design conformance to 10 CFR 50.46 criteria, and 10 CFR Part 50 Appendix K requirements. Overall, the methodology analyzes the transient chronologically in phases consisting of (1) initialization, (2) blowdown, (3) refill or spray cooling, and (4) reflood. System calculations are performed for each phase of the transient. The results of these calculations are used to provide boundary conditions for fuel assembly heatup calculations that yield fuel rod temperatures and metal-water reaction results at the plane of interest for a single fuel assembly throughout the LOCA transient.

2.2 Proposed Revisions to the Current Approved Evaluation Model

The currently approved EXEM/BWR evaluation model requires the use of plant and fuel data, core physics calculation results from CASMO and MICROBURN and steady-state thermal-hydraulic results from XCOBRA. The EXEM/BWR evaluation model codes consist of the RODEX2 code, which provides burnup-dependent fuel parameters, the RELAX code which calculates the system and hot channel blowdown transient, the FLEX code which calculates the system response during refill to the time of core reflood, and the HUXY code which takes input from the system calculation results and computes the fuel heatup of the maximum power assembly at the plane of interest over the entire LOCA transient.

Changes were made to EXEM/BWR to correct deficiencies in the methodology and to address issues raised during the 1997 NRC inspection of FRA-ANP's LOCA methodologies. The EXEM/BWR-2000 revisions described in the subject topical report represent revisions to the currently approved EXEM/BWR methodology. Only two codes, FLEX and RELAX, are affected by the changes. The RODEX2 and the HUXY codes do not change, nor do any of the codes providing input to the methodology, neither does the way these codes are applied. The principal methodology change was to run the RELAX code from the end of blowdown through the time of core reflood to replace the FLEX calculation with an extended RELAX calculation. This change eliminates the FLEX code from the methodology. Therefore, the code changes summarized below apply only to the RELAX code.

2.3 Code Changes

2.3.1 <u>Replacement of FLEX with RELAX</u>

- FLEX was originally developed to determine the time of reflood. This was done to resolve computational limitations concerning hardware and software using RELAX.

- Improved numerical techniques installed in the 1991 version of RELAX coupled with faster computers has significantly reduced the need for FLEX.

- The removal of FLEX provides the following advantages: (a) it reduces the opportunity for errors in input decks, and removes possible discontinuities which may occur, (b) it is more efficient in performing the calculations, and (c) it reduces the number of codes for maintenance and benchmarking.

- The time of reflood will now be determined using RELAX.

2.3.2 RELAX Reflood Criteria

- The mechanism which was used in FLEX for determination of reflood has been implemented into RELAX. The parameters which are used to determine if a reflood has occurred are as follows: (a) the flow of liquid must be upward through the core (bias), (b) the rate of liquid flow must be equal to or exceed a specified value (reflood rate), and (c) the flow must be equal or exceed the reflood rate for a specific amount of time. The data is smoothed over a period of half the waiting time. This serves to ignore spikes and trigger on actual refloods.

- When the above criteria have been met, the condition for the start of reflood will be acceptable.

2.3.3 Extension of OHKAWA-LAHEY Drift Flux Corelation

- The 1991 version of RELAX contains both the Ishii and Ohkawa-Lahey drift flux correlations.

- It has been proposed to remove the Ishii correlation due to a singularity which exists in the formulation.

- Removal of the Ishii drift flux correlation will also remove a discontinuity in the RELAX code when switching between the two correlations.

- The Ohkawa-Lahey drift flux correlation will now be used throughout the entire computational space of a BWR calculation.

- The Ohkawa-Lahey drift flux correlation reduces to the Kutateladze CCFL condition; therefore, it will also be used for the CCFL calculation.

2.3.4 CHF Correlations

- The applicant will use an appropriate CHF correlation approved by NRC for the applicant's fuel designs, and it will be applied within the data range envelope in which it was developed.

2.3.5 CE-EPRI Two-phase Degradation Pump Model

- The semi-scale two-phase degradation pump model in RELAX was replaced by a new and upgraded model (CE-EPRI) which should provide more realistic results for full scale plant analysis.

- The impact of this model for large break LOCA is small, and the impact for small break LOCA decreases the peak cladding temperature (PCT).

- This change typically results in LB-LOCA cases being the limiting case.

2.3.6 Over Condensation Model

- One-dimensional homogeneous equilibrium codes overpredict the amount of condensation in volumes where large amounts of subcooled liquid are injected. This results in an unrealistic, non-physical behavior of pressure suppression in that volume. However, the correct pressure behavior can be approximated by assuming the spray water is injected at or slightly below the saturation temperature corresponding to the calculated volume pressure. This is the basis for the assumption applied in the RELAX code to address this limitation of a one-dimensional homogeneous equilibrium model, and it is conservative because the beneficial effects of the subcooled liquid observed in the large scale tests is conservatively ignored in the calculation.

2.4 Modeling Application Changes and Sensitivity Study

Four modeling modifications are required for the EXEM BWR-2000 evaluation model. These are: (1) increased jet pump noding and a modified jet pump exit description, (2) a phase separation model in the bypass, (3) core nodalization, and (4) upper plenum nodalization. FRA-ANP stated that EXEM BWR-2000 evaluation model sensitivity studies have confirmed that the evaluation model analysis is not excessively sensitive to RELAX nodalization or its input. It was further stated that the EXEM BWR-2000 showed insignificant sensitivity to the average core nodalization, upper plenum nodalization, hot channel nodalization, and time steps.

3.0 EVALUATION

Assessment of the EXEM BWR-2000 ECCS evaluation model was performed by benchmark comparisons against FIST and two loop test apparatus (TLTA) experimental results. The applicant used the TLTA benchmark to assess the blowdown behavior of RELAX. The submittal shows that blowdown calculations of the TLTA benchmark produce the expected results. The lower plenum inventory, as well as the steam dome pressure, are predicted better by EXEM BWR-2000 than by EXEM/BWR evaluation model. Other parameters are similar to, but show minor differences from, EXEM/BWR results. The results also exhibit acceptable physical trends. The hottest nodal temperature predicted by RELAX using EXEM BWR-2000 is conservative with respect to data.

Benchmark calculations of three FIST tests were performed: two large break cases (6DB1-B and 4DBA1), and one small break case (6SB2C). The hydraulics and mass inventories were conservatively predicted, and the large-break design-basis accident (DBA) PCTs were conservatively calculated. The test results for small breaks produced very low PCTs, and the EXEM BWR-2000 model using evaluation model options bounds the temperature data. Furthermore, the EXEM BWR-2000 model adequately predicts other, important LOCA phenomena.

After completing its initial review, the staff issued requests for additional information (RAIs) regarding EXEM BWR-2000 evaluation model, and the applicant submitted responses to those RAIs (References 3, 4, 5 and 6). Some of those responses are discussed below.

The staff requested the applicant to verify whether there is any potential for introducing human error while transferring data from RELAX to FLEX in the current evaluation model EXEM/BWR, and whether the proposed EXEM BWR-2000 would remove this potential source of error while using the code. The applicant responded that the current evaluation model, EXEM/BWR, has a small potential for introducing human error in the specification of the files to be transferred between FLEX and RELAX. The EXEM BWR-2000 model does not use the FLEX code, and no data transfer is necessary. Thus, the potential for human error in this data transfer has been eliminated.

It was stated in the submittal that results from EXEM BWR-2000 calculations of the FIST and TLTA tests, which are single channel results, will always give conservative PCT compared to large tests with multiple parallel channels of varying power, or the actual BWR behavior during LOCA. This is because spray coolant can easily bypass hot assemblies and reach the lower plenum through colder peripheral assemblies resulting in faster refill and reflood. It was further stated that single channel tests and code results do not reflect this phenomenon, and hence include inherent conservatism. The staff requested the applicant to provide an estimated value of PCT reduction due to this phenomenon. FRA-ANP responded that the PCT conservatism inherent in single channel test and code results was estimated to be about 380°F. One of the simplifying assumptions made to estimate the PCT reduction in multiple channels was that all of the mass that is injected into the upper plenum and in the bypass volume goes straight to the lower plenum. A more detailed calculation would, however, show some holdup in the bypass volume as well as some changes in the swelling calculation of the lower plenum. These effects would reduce this PCT estimate somewhat, but are still expected to leave considerable conservatism in the predicted value of the PCT.

In order to verify the code performance, and to reproduce some of the results presented in the subject topical report, the staff requested the applicant to supply the source code, the executable version of the code, the user code documentation, and specific input models for one large-break and one small-break LOCA. After receiving the requested items from the applicant, the staff ran the code on an NRC computing system, and independently verified some of the results and conclusions reported in the submittal.

4.0 CONCLUSION

On the basis of its review of the information presented in the subject topical report, and the supporting information in the applicant's response to the staff's RAIs as discussed in the section above, the staff has determined that the EXEM BWR-2000 methodology has been simplified from the current methodology by the removal of FLEX, and replacing it with RELAX. The staff also determined that there is reasonable assurance that the FRA-ANP methodology using the RELAX code to simulate the blowdown and refill/reflood periods of a LOCA, and the HUXY code for the heat-up period will produce conservative PCTs. The staff notes that from validation against test data, the large-break DBA PCTs were conservatively calculated. The test results for small breaks show low temperatures, and the EXEM BWR-2000 model using evaluation model options bounds the temperature data. Furthermore, the EXEM BWR-2000 model adequately predicts the important LOCA phenomena.

The staff, therefore, concludes that the proposed EXEM BWR-2000 ECCS EM, as documented in References 1, 2, 4 and 5, is acceptable for referencing in BWR LOCA analyses, with the limitation that application of the revised evaluation model will be limited to jet pump plant applications.

5.0 REFERENCES

1. EMF-2361(P), Revision 0, "EXEM BWR-2000 ECCS Evaluation Model," by S. E. Jensen, et al., October 2000.

2. Letter from J. F. Mallay, SPC to NRC, "Request for Review of EMF-2361(P), Revision 0, EXEM BWR-2000 ECCS Evaluation Model," November 7, 2000.

3. Letter from J. F. Mallay, FRA-ANP to NRC, "NRC Review of EMF-2361(P), Revision 0, EXEM BWR-2000 ECCS Evaluation Model," March 1, 2001.

4. Letter from J. F. Mallay, FRA-ANP to NRC, "Request for Additional Information - Framatome ANP Richland, Inc., Topical Report EMF-2361(P), Revision 0, EXEM BWR-2000 ECCS Evaluation Model," March 23, 2001.

5. Letter from J. F. Mallay, FRA-ANP to NRC, "Response to RAI Request Number 6 for Topical Report EMF-2361(P), Revision 0, EXEM BWR-2000 ECCS Evaluation Model," April 12, 2001.

6. Letter from J. F. Mallay, FRA-ANP to NRC, "Request for Additional Information - Framatome ANP Richland, Inc., Topical Report EMF-2361(P), Revision 0, EXEM BWR-2000 ECCS Evaluation Model," May 2, 2001.

7. XN-235(A), *Exxon Nuclear Evaluation Model for BWR Loss of Coolant Accident*s, Exxon Nuclear Company, January 1986.

8. XN-75-55(A), Revision 2 and Supplements 1 and 2, *The Exxon Nuclear Company WREM-Based NJP-BWR ECCS Evaluation Model and Application to the Oyster Creek Plan*t, Exxon Nuclear Company, April 1976.

9. XN-NF-80-19(P)(A), Volumes 2, 2A, 2B, and 2C, *Exxon Nuclear Methodology for Boiling Water Reactors: EXEM BWR ECCS Evaluation Mode*l, Exxon Nuclear Company, September 1982.

10. ANF-91-048(P)(A), *Advanced Nuclear Fuels Corporation Methodology for Boiling Water Reactors EXEM BWR Evaluation Mode*l, Advanced Nuclear Fuels Corporation, January 1993.

11. ANF-91-048(P)(A), Supplements 1 and 2, *BWR Jet Pump Model Revision for RELAX,* Siemens Power Corporation, October 1997.

Principle Contributor: M. M. Razzaque

Date: May 29, 2001