April 9, 2002

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

SUBJECT: SAFETY EVALUATION OF FRAMATOME TECHNOLOGIES TOPICAL REPORT BAW-10164P REVISION 4, "RELAP5/MOD2-B&W, AN ADVANCED COMPUTER PROGRAM FOR LIGHT WATER REACTOR LOCA AND NON-LOCA TRANSIENT ANALYSES" (TAC NOS. MA8465 AND MA8468)

Dear Mr. Mallay:

By letters dated September 24, 1999 and February 29, 2000, Framatome submitted BAW-10164P, Revision 4, "RELAP5/MOD2-B&W, An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analyses," for review by the NRC staff. By letters dated September 5, 2000, March 23, 2001, and June 15, 2001, Framatome provided additional information.

Framatome proposed the following changes to BAW-10164P-A (as Revision 4) and refinements to the loss of coolant accident (LOCA) evaluation models (EMs):

1. A change that will model the hot channel modeling to treat the hot pin and the hot assembly as two heat structures for large break LOCA (LBLOCA) evaluations of recirculating steam generator (RSG) and once through steam generator (OTSG) plants,

2. A change to the initial fuel stored energy uncertainty that will apply a lower uncertainty in the initial fuel stored energy, derived from TACO3, to the hot assembly and core average heat structures for LBLOCA evaluations of RSG and OTSG plants,

3. A change to automate the void-dependent cross-flow model and to interpolate the inter-channel void-dependent cross-flow for small break LOCA (SBLOCA) evaluations for OTSG plants, and

4. Automation of the core heat BEACH blockage limitation that will automate flow-blockage limit in BEACH, used for LBLOCA and SBLOCA analyses of RSG and OTSG plants.

The staff has completed its review of the subject topical report (TR) and finds it is acceptable for referencing in licensing applications to the extent specified and under the limitations delineated in the report and in the associated safety evaluation (SE). The SE defines the basis for 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 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.

We do not intend to repeat our review of the matters described in the subject report, and found acceptable, when the report appears as a reference in license applications, except to ensure that the material presented applies to the specific plant involved. Our acceptance applies only to matters approved in the report.

In accordance with the guidance provided in NUREG-0390, we request that Framatome publish an accepted version of this TR within 3 months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed safety evaluation between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain in appendices historical review information, such as questions and accepted responses, and original report pages that were replaced. The accepted version shall include an "-A" (designated accepted) following the report identification symbol.

Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, Framatome and/or the applicants referencing the TR will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the TR without revision of their respective documentation.

Sincerely,

/RA/
Leslie W. Barnett, Acting Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 693

Enclosure: Safety Evaluation

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 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.

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Sincerely,
/RA/
Leslie W. Barnett, Acting Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 693

Enclosure: Safety Evaluation

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT BAW-10164P, REVISION 4, "RELAP5/MOD2-B&W,

AN ADVANCED COMPUTER PROGRAM

FOR LIGHT WATER REACTOR LOCA AND NON-LOCA TRANSIENT ANALYSES"

PROJECT NO. 693

1.0 INTRODUCTION

Framatome ANP proposed several changes to its loss-of-coolant accident (LOCA) evaluation models (EMs) and methodologies in letters dated September 24, 1999 and February 29, 2000. Framatome provided additional information by letters dated September 5, 2000, March 23, 2001, and June 15, 2001.

Framatome ANP maintains several LOCA EMs to cover the conditions of small break LOCAs (SBLOCAs) and large break LOCAs (LBLOCAs) in once-through steam generator (OTSG) plants and recirculating steam generator (RSG) plants. The LOCA EMs are described in several Framatome topical reports, including the following:

BAW-10168P-A, "RSG LOCA, BWNT Loss-of Coolant Accident Evaluation Model for Recirculating Steam Generator Plants," Revision 3, December 1996.

BAW-10192P-A, "BWNT LOCA, BWNT Loss of Coolant Accident Evaluation Model for Once-Through Steam Generator Plants," Revision 0, June 1998.

BAW-10164P-A, "RELAP5/MOD2-B&W, An Advanced Computer Program for Light Water Reactor LOCA and Non-LOCA Transient Analyses," Revision 3, July 1996.

BAW-10166P-A, "BEACH, Best Estimate Analysis Core Heat Transfer, A Computer Program for Reflood Heat Transfer During LOCA," Revision 4, February 1996.

BAW-10162P-A, "TACO3, Fuel Rod Thermal Analysis Computer Code," Revision 0, November 1989.

Framatome proposed the following changes to BAW-10164P-A (as Revision 4) and refinements to the LOCA EMs:

1. A change that will model the hot channel modeling to treat the hot pin and the hot assembly as two heat structures for LBLOCA evaluations of RSG and OTSG plants,

2. A change to the initial fuel stored energy uncertainty that will apply a lower uncertainty in the initial fuel stored energy, derived from TACO3, to the hot assembly and core average heat structures for LBLOCA evaluations of RSG and OTSG plants,

3. A change to automate the void dependent crossflow model and to interpolate the inter-channel void-dependent cross-flow for SBLOCA evaluations for OTSG plants, and

4. Automation of the core heat BEACH blockage limitation that will automate flow-blockage limit in BEACH, used for LBLOCA and SBLOCA analyses of RSG and OTSG plants.

2.0 STAFF EVALUATION

The staff reviewed the above proposed changes for acceptability in the context of the previously approved LOCA EMs listed above (e.g., Revision 3 to BAW-10164P-A, Revision 3 to BAW-10168P-A, and Revision 0 to BAW-10192P-A). These EMs will use the RELAP 5 code described in BAW-10164P, Revision 4.

The staff's review of the changes to the hot channel modeling, fuel initial stored energy uncertainty, cross-flow modeling, and flow blockage limit automation, in the context of the previously approved LOCA EMs, is presented below.

2.1 Changes to the Hot Channel Modeling in the LBLOCA Methodology

By letters dated September 24, 1999, and February 29, 2000, Framatome described the changes to the hot assembly modeling. Additional information was provided in letters dated September 5, 2000, March 23, 2001, and June 15, 2001. The changed modeling applies to the RELAP5/MOD2-B&W LBLOCA EMs for OTSG (BAW-10192P-A, Revision 0) and RSG (BAW-10168P-A, Revision 3) plants. The principal amended changes are: (a) replacing the hot rod/hot assembly channel with one channel containing two heated surfaces, one representing the hot rod and the other representing the other rods in the hot assembly, and (b) using the fuel initial stored energy uncertainty, and corresponding initial fuel rod conditions, as discussed in Section 2.2.

Currently, the Framatome model for peak cladding temperature (PCT) calculations does not differentiate between the hot fuel assembly and the hottest pin. This modeling scheme causes the entire hot assembly to incorporate all of the conservatisms required for the hot pin or hot spot to assure that the hot pin or hot spots are not under predicted. In the present model, Framatome assumes that the hot assembly consists of all hot rods at the peak rod power and peaking factors, and at the hottest rod initial temperature (stored energy) uncertainty. Framatome contends that this model results in a significant overprediction of the severity of the hot pin or hot spot conditions, and a very conservative prediction of the PCT. Framatome also contends that this conservative modeling did not represent the actual physical phenomenon in that there are cooling mechanisms affecting the hot spot. Framatome contends that these cooling mechanisms include convective heat transfer when there is high coolant flow, and a radiative heat transfer process to the immediate surroundings of the hot spot during low coolant flow. The cooling mechanisms govern heat transfer between the hot spot and the hot fuel assembly.

Therefore, Framatome proposed a new model which separates hot pin and hot spots from the hot fuel assembly. In the proposed model, the power of the rods in the core is assumed to be the same as in the present model, with all rods in the hot assembly at the same limiting power. However, in the proposed version, the initial conditions of temperature uncertainties for the fuel rods in the hot assembly are changed based on TACO3 calculations. The hottest rod uncertainty remains the same as assumed in the present model. The remainder of the rods in the hot assembly have an initial temperature uncertainty, derived from TACO3 calculations, statistically based on the fuel rods immediately surrounding the hottest rod. This lowers the temperature uncertainty assumption for all the fuel rods in the hot assembly except for the hottest rod. In addition, the average core heat structure will be initialized with no uncertainty, consistent with the above statistical approach. The fuel temperature uncertainty is discussed in more detail in Section 2.2 of this safety evaluation. The rest of the rods in the core are modeled the same as in the present model.

The changes would not affect the hot rod directly. The hot rod would be represented the same as it is in the present model. However, the changes to the initial conditions including the stored energy of the other rods, would in turn change the transient effects of the other rods. The transient effects of the other rods would affect the transient coolant conditions of the hot channel, and thereby affect the transient behavior of the hot rod. The overall result of the reduced conservatism of the non-hot rod initial conditions is a lowering of the calculated peak cladding temperature.

The staff concludes that the change to two heat surfaces in the hot channel and the changes in assumed initial fuel temperature uncertainty are acceptable because the methodology continues to assume that all the fuel rods in the hot assembly are at the same limiting power and peaking factors as the hottest rod. The staff expects the assumed power level in the hot assembly to be sufficiently conservative such that the EM, using the initial fuel temperature uncertainty discussed below, will provide conservative results.

In summary, the staff concludes that the hot channel modeling changes are acceptable for the proposed version of the methodology because the Framatome assumption that all the hot assembly fuel rods are at the hottest rod's power assures that the methodology will continue to be conservative when changes reducing the conservatism of the initial fuel temperature uncertainty are included.

2.2 Changes to Initial Fuel Stored Energy Uncertainty

By letter dated February 29, 2000, Framatome proposed changes to the uncertainty applied to the fuel initial stored energy. As previously discussed, the current Framatome model for PCT does not differentiate between the hot fuel assembly and the hottest pin. This modeling scheme causes the entire hot assembly to incorporate all of the conservatisms required for the hot pin or hot spot to assure that the hot pin or hot spot is not underpredicted. As a result, in the current EM, Framatome applies an uncertainty that is applicable to the hot spot to the entire hot assembly and hot pin. The stored energy in the fuel is derived from the approved TACO3 fuel performance code.

Framatome's proposed new model includes a hot pin modeled as a separate heat structure that shares a coolant channel with the hot fuel assembly. The hot fuel assembly is comprised of all fuel pins within the hot assembly except the hot pin. For the hot pin, Framatome will use an initial fuel temperature uncertainty of 11.5 percent, which is based on the hot spot. This is the same uncertainty value as is used for the hot rod/assembly in the current model. Thus, the stored energy for the hot pin is identical for both current and proposed models. The staff considers this approach acceptable.

The initial fuel temperature uncertainty for the hot fuel assembly is determined by a probability distribution of the fuel pellet temperature predictions such that the temperature is overpredicted 95 percent of the time at the 95 percent confidence level. To deduce the average fuel temperature uncertainty for the hot fuel assembly, Framatome described a flow channel that shows a hot pin surrounded by eight fuel pins to form four subchannels. Framatome contended that only pins and pellets within these subchannels can be expected to affect the heat transfer from the hot spot. This approach effectively shields the hot pin from influence by those pins outside the channel, thereby conservatively predicting fuel temperature uncertainty. Framatome assigned weighting factors for those eight pins surrounding the hot pin that contribute heat to the subchannels. These weighting factors are based on a conservative geometrical consideration that maximizes the heat added to the subchannels. Framatome notes that there is an additional conservatism because the control rod guide tubes and instrument tubes are not considered in the hot fuel assembly. To determine the average uncertainty for the fuel pellets surrounding the hot pin, Framatome applied a statistical method to randomly determine the uncertainty of each pellet, according to the TACO3 uncertainty distribution, and considered the applicable heat transfer mechanisms at the hot spot. This process was repeated until a 95/95 confidence level was reached. The result showed that the average uncertainty for the hot fuel assembly is 2.1 percent for conditions with coolant flow and 2.3 percent for conditions without coolant flow. For conservatism, Framatome will assign an average uncertainty of 3 percent for the hot assembly. Based on this average uncertainty, Framatome can calculate the stored energy for the hot fuel assembly. The staff agrees with this approach.

Similar to the calculation of hot assembly uncertainty, Framatome evaluated the average uncertainty to be applied to the average core heat structure. Framatome determined that, core wide, the average uncertainty is zero (e.g., no bias in the TACO3 results). Framatome noted, however, that a correction to the TACO3 results is applied for high burnup fuel (greater than 40 GWd/mtU), consistent with the high burnup Topical Report, BAW-10186P-A, "Extended Burnup Evaluation," Revision 0, June 1997.

The staff has reviewed Framatome's proposed stored energy model for hot pin, hot fuel assembly, and average core heat structures. Based on the approved TACO3 code and conservative approach in the modeling and statistical method, the staff finds the proposed changes to be acceptable.

2.3 Changes to Void-Dependent Cross-Flow Model

Framatome proposed to change its small break LOCA analysis methodology as described in their September 24, 1999, letter. The staff also consulted BAW-10192P-A, Volume 2, which described the previous SBLOCA methodology for B&W designs. The previous methodology provides coefficients controlling cross-flow in the core between the hot channel and the average channel in both directions for both below the water surface and the steam space above the water surface. The values of the coefficients used in the approved model were determined by analytical sensitivity studies to assure relative conservatism and consistent calculated behavior. No formal comparisons to test data were performed. The time-dependent variance of the fluid condition at any given level determines the values of these coefficients at that level. In the present methodology, coefficient values were entered by the analyst in an iterative process of interpretation of the calculated time- and level-dependent fluid conditions.

The existing core cross-flow model provides flow coefficients between the hot channel and the average channel. The coefficients are fixed-valued, but specific to the flow location (above and below the water surface) and the flow direction (out of the hot channel or into the hot channel from the average channel). In the previous model, the values of the time-dependent coefficient values were determined by the analyst's assessment of the time variance of fluid conditions in the channels. The specific values were initially checked against large break data, and then tuned with sensitivity studies to give qualitatively credible results and identify the bounding case of those studied. This was considered by the staff in its previous review and approval of the model.

The proposed model change adds a void-dependent transition zone (which varies in elevation with the time-dependent change in core water level) to interpolate the coefficients, providing greater continuity to the calculations. In the updated methodology, the interpretation of time- and level-dependent fluid condition is automated, avoiding the possible inconsistencies introduced by different interpretations between analysts.

In a letter dated March 23, 2001, Framatome stated that it examined the relative effect of this change for a limited number of cases that they considered representative. In comparisons of results using the previous model and results using the proposed model, the calculated results using the proposed model are consistent and fall within the range of variance between different analysts using the previous model. This demonstrates that, for SBLOCA analyses representative of B&W-design licensing cases, use of the proposed model yields results within the range of results using the previously approved model.

The staff concludes that the proposed treatment of cross-flow is acceptable for the proposed version of the SBLOCA methodology because the proposed automated cross-flow model provided more consistent results than the previously approved analyst-controlled model, and because the results using the proposed model fell within the range of variance of the results using the previously approved analyst-controlled model in comparisons performed by Framatome.

Future changes to the Framatome SBLOCA methodology could significantly affect either the form of the cross-flow model or the cross-flow coefficient values. Because the staff only considered the proposed cross-flow model within the context of the Framatome SBLOCA methodology as it is presently configured, and for scenarios represented in a limited sensitivity study, future modifications of the SBLOCA methodologies could compromise any conservatism remaining in the methodology. The staff will in future reviews of SBLOCA model changes, request additional empirical data comparisons supporting the cross-flow model discussed in this safety evaluation to confirm that sufficient conservatism remains in the future methodologies in accordance with 10 CFR Part 50, Appendix K.

Plant design and fuel differences, and discovered errors or changes, could affect the results, both quantitative and qualitative, due to the form of the cross-flow model or the cross-flow coefficient values. Differences in the results could indicate different compensatory or remedial actions. Deviations from the versions of the LOCA methodologies containing the cross-flow model discussed in this safety evaluation are subject to the requirements of 10 CFR 50.46.

2.4 Automation of BEACH Blockage Limitation

The approved version of the BEACH methodology contains a credited flow blockage limitation of 60 percent, which is implemented by the analyst inspecting the analytical results. In the September 24, 1999, letter, Framatome proposed to automate this limit in the BEACH coding. This automation is more convenient, and makes implementation of the limitation and calculated results more reliable and consistent. For these reasons, the staff finds this change acceptable.

3.0 CONCLUSIONS

Based on reviews discussed in Section 2, the staff finds the following Framatome proposed methodology changes (BAW-10164P, Revision 4) acceptable within the stated terms and limitations:

1. A change that will model the hot channel modeling to treat the hot pin and the hot assembly as two heat structures for LBLOCA evaluations of RSG and OTSG plants.

2. A change to the initial fuel stored energy uncertainty that will apply a lower uncertainty in the initial fuel stored energy, derived from TACO3, to the hot assembly and core average heat structures for LBLOCA evaluations of RSG and OTSG plants.

3. A change to automate the void dependent crossflow model and to interpolate the inter-channel void-dependent cross-flow for SBLOCA evaluations for OTSG plants.

4. Automation of the core heat BEACH blockage limitation that will automate the flow-blockage limit in BEACH, used for LBLOCA and SBLOCA analyses of RSG and OTSG plants.

For reasons discussed in Section 2, in its review of future changes to the LBLOCA and SBLOCA methodologies beyond the context discussed in this safety evaluation, the staff will closely examine the impacts of the proposed changes with respect to the TACO3 stored energy model, the hot channel modeling changes, and the cross-flow model discussed in this safety evaluation.

As discussed in Section 2, the methodology changes addressed in this safety evaluation are significant. They involve both LBLOCA and SBLOCA, and a variety of plant designs, including recirculating steam generator and once-through steam generator designs. The methodology changes would likely affect the various plant designs differently. Identified errors and changes, and compensatory and remedial actions could be different between the plants. Deviations from the versions of the LOCA methodologies containing the items discussed in this safety evaluation (BAW-10164P, Revision 4) are subject to the requirements of 10 CFR 50.46.

Principal Contributor: F. Orr

Date: April 9, 2002