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Closure of Interim Report 03-001, "Fuel Assembly Bow Analysis"

Ref.: 1. Letter, James F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Interim Request of an Evaluation of a Deviation Pursuant to 10 CFR 21.21(a)(2)," NRC:03:083, December 9, 2003.

Ref.: 2. BAW-10147(P)(A), Revision 1, "Fuel Rod Bowing in B&W Fuel Designs," May, 1983.

Ref.: 3. XN-75-32(P)(A) Supplements 1 through 4, "Computational Procedure for Evaluating Fuel Rod Bowing," Exxon Nuclear Company, October 1983.

An interim report was made to the NRC concerning the analysis of a potential for fuel assembly bow (Reference 1). The final evaluation of this situation has been completed and Framatome ANP has concluded that the deviation is not reportable under 10CFR21.

Framatome ANP's evaluation, including a summary of results, is provided in Attachment A. We have concluded that the analyses performed in accordance with the previously approved topical report (Reference 2) remain valid for the pertinent fuel assembly designs. As explained in the attachment, this conclusion is based on a number of considerations, including the fact that no new operational evidence has been identified that would indicate any adverse effects from a postulated fuel assembly bow.

Framatome ANP has two approved topical reports concerning assembly bow (References 2 and 3). The methods used in these two reports differ from each other. The issue that led to this evaluation affects only Reference 2. However, since the magnitude of the assumed assembly bow is arbitrary in both reports, the discussion of the magnitude of the assembly bow in Attachment A applies to both methods.

Very truly yours,

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Enclosures

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Attachment A

Evaluation of Assembly Bow

Introduction

An interim report was issued by Framatome ANP to the NRC in December 2003, under the provisions of Part 21, concerning the analysis of potential fuel assembly bow (Reference 1). This interim report stated that the evaluation of the matter was expected to be completed by December 2004. This report summarizes the issue that was raised in 2003, the results of our evaluation, and the conclusion reached that the matter is not reportable under 10CFR21.

Framatome ANP has calculated the effects of fuel assembly bow for Mark-B and Mark-BW fuel in accordance with an NRC-approved methodology (Reference 2), which was accepted in May 1983. Because this approval was obtained many years ago and because there has been some maturity in the analytical techniques during this time, questions were raised about the adequacy of the assumptions and methods used to assess the effects of a potential fuel assembly bow.

The evaluation of assembly bow focuses primarily on two aspects of the analysis: the assumed gap size and the method used to calculate the resulting power peaking.

Summary

Framatome ANP has concluded that the methodology contained in the approved topical report continues to be applicable and is acceptable. This conclusion is based in part on the status of current knowledge. After detailed investigation, no evidence of the effects of assembly bow has been found. Nor has any additional information been obtained about assembly bow during operation, such as gap measurements, since the approval of the topical report (and the approvals of similar topical reports from the other vendors in the same time frame).

The evaluation of this matter considered whether there are other conservatisms associated with normal operation and with transient analyses that would more than compensate for the effects of assembly bow, were it to occur. It was concluded that any effects of assembly bow during operational or transient conditions would fall within the known conservatisms associated with the approved techniques for analyzing those conditions.

Assessment of Assembly Bow

There are no measured data available concerning the magnitude, distribution, or axial dependence of assembly bow during operation. Observations have been made of bowed fuel assemblies in the cold condition after removal from a variety of reactors, but these distortions have not been correlated to in-reactor behavior. Specifically, prior to the development of the topical report (Reference 2), out-of-reactor observations were made that would imply that bow to contact is possible during operation. Following approval of the topical report, similar observations have been made on Mark-B and Mark-BW assemblies as well as PWR assemblies of a different design in Europe. Based on this limited set of out-of-reactor observations, we are still left to speculate about the magnitude of assembly bow during operation.

Our topical report concluded that the interaction of assemblies in a reactor (that is, in a restrained condition and with a defined geometry) would result in less assembly bow than observed outside the reactor at ambient conditions. Therefore, we concluded, and the NRC agreed, that it was reasonable to assume that an assembly could bow to contact with an adjacent assembly. However, as mentioned in our interim report, there could be a potential for bow magnitudes larger than bow to contact to occur during operation.

Several evaluations have been performed to determine whether any post-irradiation measurements were available of oxidation, fission gas generation, incore power distributions, or other factors that might support an estimate of the magnitude of an assembly bow. No indications of adverse effects that could be attributed to assembly bow were found, nor any basis revealed to estimate the degree of assembly bow. (It was recognized during this evaluation that the amount of assembly bow would have had to be quite large to be detected by any of these measurement techniques.) In addition, it was concluded that incore detectors are incapable of detecting increased peaking along any one edge of an assembly.

We conclude there is no reason for making any specific assumption regarding the size of the gap due to assembly bow. In the approved methodology, bow to contact is assumed, and we conclude this assumption is adequate, despite the inability to conclusively demonstrate whether it is conservative.

Consideration of Larger Assembly Bows

Although it is theoretically possible to develop a method to estimate in-reactor assembly bow based on out-of-reactor measurements, there is no means to validate such a technique. Also, more conservative peaking factors can be calculated if observed out-of-reactor bow is assumed achievable during operation, but such an assumption cannot be quantified and is therefore not meaningful.

We conclude, therefore, that there is no basis for making these types of calculations.

Calculation of Peaking Effects

In addition to the question about the magnitude of assembly bow, the interim report (Reference 1) outlined three parts of the approved methodology where analytical enhancements could be made. Specifically, the assumed gap size was based on cold dimensions, diffusion theory was used to determine the change in peaking due to assembly bow, and the geometry used to perform the calculation represented a symmetric fraction of the assembly only.

Revised analyses using hot dimensions, transport theory, and full assembly geometry were conducted. These calculations were conducted in order to provide a bounding result for those customers who needed a basis for continued operation while the evaluation of the matter proceeded. The results of these analyses were temporarily adopted by two licensees.

In addition, these calculations included the added conservatism that contact was assumed to occur at the corners of adjacent assemblies and at the axial location of maximum peaking. Achieving corner to corner contact would be difficult because of the added stiffness in the diagonal direction. The result of this calculation showed a peaking factor increase for a corner rod of 7.8 percent, compared to the 2.8 percent increase shown in the approved topical report (Reference 2).

Because we have concluded that additional penalties are not required, the conclusions reached and reported on in this evaluation justify removal of these temporary, additional penalties.

Historical Perspective

The uncertainties associated with the assumption of the magnitude of assembly bow and the calculation of the increased peaking factor were clearly recognized during the NRC review and approval of the topical reports submitted by each vendor. The approach taken by the NRC in all these reviews was to qualitatively assess the degree of assembly bow and its peaking factor effect and to qualitatively assess the margins available in performing safety analyses that would compensate for the effects of assembly bow.

Based on our reevaluation of assembly bow, this approach remains valid.

Conservative Nature of Safety Analyses

An assessment has been made of the known, but unquantified, conservatisms that result from the use of analytical methods to establish safety limits for normal operation and for transients. There are a limited number of key parameters involved in these analyses, and they are discussed below.

<u>Burnup</u>. If a pin is assumed to operate at a higher power than designed (for example, because of assembly bow), it will deplete faster than predicted and will burn down to a lower peaking factor, thus relieving any temporary peaking. This factor has been cited by the NRC in approving previous evaluations of assembly bow (Reference 2).

<u>Computation of Fq</u>. It can be shown that there is about a 4 to 6 percent difference in Fq depending on whether the uncertainties associated with the peaking due to assembly bow are simply multiplied or whether they are statistically convoluted. This difference is mildly plant-specific, but is in this range for the Mark B and Mark BW designs.

<u>Operational Value of Fq</u>. There is about a 20 percent difference between the tech spec value of Fq and the value of Fq experienced in a normal equilibrium state, which is the condition reactors are operated at for more than 95 percent of the time. Even if assembly bow caused local peaking effects, this peaking would have an effect for an extremely limited time during operation and would only be of significance if the tech spec limit on Fq were approached.

<u>LOCA Limits</u>. The ECCS criteria used to evaluate the effects of a LOCA were established to ensure a coolable geometry during and after the event. The primary conservatism in the ECCS criteria is the requirement that the hot spot in the core satisfy these criteria. However, coolability would be ensured even if limited, local regions of the core violated the criteria. Also, the peak cladding temperature and peak local oxidation criteria were set conservatively low.

<u>DNB</u>. Fuel failures are assumed to occur when the critical heat flux is reached. In reality, the fuel rod must be in CHF for some period of time prior to creating a failure. No method is available to estimate the degree of this conservatism, but it would appear to be significant because DNB is typically calculated to occur for very brief periods (if at all).

<u>Centerline Melt</u>. As in the case of DNB, fuel failures are assumed to occur when the centerline of a pellet reaches the melting temperature. However, a fuel rod will not fail until a significant fraction of the pellet reaches the melting temperature. Again, there is no benchmarked method to estimate the degree of conservatism in this failure assumption but it appears significant because of the added energy required to melt a substantial fraction of the fuel.

Conclusions

There is no quantitative basis for assigning a specific peaking penalty because of an assumed assembly bow. First, we lack specific knowledge about the assembly behavior during operation. Second, there is general acceptance that substantial conservatisms exist in the analysis of normal operation and in the assumed failure modes during transients.

In reviewing the safety evaluation for the approved topical report, the NRC appears to have reached the same conclusion about the lack of a need to impose an arbitrary penalty due to presumed but uncharacterized assembly bow during operation. The approved topical reports on assembly bow (for all PWR vendors) and the associated safety evaluations clearly attempted to balance the qualitative discussion of the potential peaking against the qualitative assessment of the conservatisms that exist in the analytical models.

We conclude this approach remains the most reasonable way to assess the effects of assembly bow because of the lack of any information to better quantify these effects. Further, we conclude that our topical report (Reference 2), which is used to assess the behavior of assemblies containing both UO2 and MOX fuel, remains valid. These conclusions are bolstered by the existence of numerous conservatisms included in all safety analyses, which ensures the retention of adequate safety margins.

References

1. Letter, J. F. Mallay (Framatome ANP) to NRC (Document Control), "Interim Report of an Evaluation of a Deviation Pursuant to 10CFR21.21(a)(2)," NRC:03:083, December 9, 2003.

2. BAW-10147PA, revision, 1, "Fuel Rod Bowing in Babcock & Wilcox Fuel Designs," May 1983.