July 1, 2004

Mr. James F. Mallay
Director, Regulatory Affairs
Framatome ANP
3815 Old Forest Road
Lynchburg, VA 24501

SUBJECT: FINAL SAFETY EVALUATION FOR FRAMATOME ANP TOPICAL REPORT BAW-10239(P), REVISION 0, "ADVANCED MARK-BW FUEL ASSEMBLY MECHANICAL DESIGN TOPICAL REPORT" (TAC NO. MB7551)

Dear Mr. Mallay:

On April 30, 2002, as supplemented by letters dated May 9, 2003, February 9 and March 18, 2004, Framatome ANP (FANP) submitted Topical Report (TR) BAW-10239(P), Revision 0, "Advanced Mark-BW Fuel Assembly Mechanical Design Topical Report," to the staff. On March 30, 2004, an NRC draft safety evaluation (SE) regarding our approval of BAW-10239(P) was provided for your review and comments. By letter dated April 23, 2004, FANP commented on the draft SE. The staff's disposition of FANP's comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter

The staff has found that BAW-10239(P), Revision 0, is acceptable for referencing in licensing applications for Westinghouse 3- and 4-loop designed pressurized water reactors with 17 x 17 fuel rod arrays to the extent specified and under the limitations delineated in the TR and in the enclosed SE. The SE defines the basis for acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that FANP publish accepted proprietary and non-proprietary versions of this TR within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed SE between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain historical review information, such as questions and accepted responses, draft SE comments, and original TR pages that were replaced. The accepted version shall include a "-A" (designating accepted) following the TR identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, FANP and/or licensees referencing it will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing.

Sincerely,
/RA/

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Safety Evaluation

July 1, 2004

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, FANP and/or licensees referencing it will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing.

Sincerely,

/RA/

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 728

Enclosure: Safety Evaluation

DISTRIBUTION:
PUBLIC
PDIV-2 Reading
RidsNrrDlpmLpdiv (HBerkow)
RidsNrrPMMHoncharik
RidsNrrLAEPeyton
RidsOgcRp
RidsAcrsAcnwMailCenter
RidsNrrDlpmLpdiv1 (RGramm)
UShoop
FAkstulewicz

ADAMS Accession No.: ML041840164 NRR-106

OFFICE	PDIV-1/PM	PDIV-2/LA	SRXB/SC	PDIV-2/SC	PDIV/D
NAME	MHoncharik:mp	EPeyton	FAkstulewicz	SDembek	HBerkow
DATE	7/1/04	7/1/04	6/30/04	7/01/04	7/1/04

DOCUMENT NAME: C:\ORPCheckout\FileNET\ML041840164.wpd

OFFICIAL RECORD COPY

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

BAW-10239(P), REVISION 0, "ADVANCED MARK-BW FUEL ASSEMBLY

MECHANICAL DESIGN TOPICAL REPORT"

FRAMATOME ANP

PROJECT NO. 728

1.0 INTRODUCTION

By letter dated April 30, 2002, and supplemental letters dated May 9, 2003, February 9 and March 18, 2004, (References 1 through 4), Framatome ANP (FANP) requested approval of Topical Report (TR) BAW-10239(P), Revision 0, "Advanced Mark-BW Fuel Assembly Mechanical Design Topical Report." Approval would permit licensees with Westinghouse three- and four-loop reactors that use a 17 x 17 fuel rod array to reference the generic TR for use of the FANP Advanced Mark-BW fuel. The FANP Advanced Mark-BW design is an evolution of the Mark-BW fuel design and includes new design features. This TR evaluated the performance of the Advanced Mark-BW fuel design against the design criteria defined in the Standard Review Plan (SRP), Section 4.2, "Fuel System Design" (Reference 5). Additionally, this TR extends the use of the fuel design change process defined in EMF-92-116(P)(A), "Generic Mechanical Design Criteria for PWR Fuel Designs," (Reference 6) using the design criteria defined within this TR for use in evaluating small changes to the Advanced Mark-BW fuel assembly design.

The staff approves use of this TR subject to the following conditions:

(1) This fuel assembly design is approved for use with low enrichment uranium (LEU) fuel, which has been enriched to less than or equal to 5 percent.

(2) The Advanced Mark-BW fuel assembly design is licensed for a maximum fuel rod burnup of 62,000 Megawatt-days/metric ton (MWD/MT).

2.0 REGULATORY EVALUATION

Fuel designs must ensure that the reactor core will have appropriate margin to assure that the specified acceptable fuel design limits (SAFDLs) criteria in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Appendix A, General Design Criterion (GDC) 10, *Reactor Design*, are met. Additionally, GDC 27, *Combined Reactivity Control System Capability*, and GDC 35, *Emergency Core Cooling*, require that licensees maintain control rod insertability and core coolability. Loss-of-coolant accident (LOCA) coolability requirements are contained in 10 CFR 50.46. The staff review process for new fuel designs is contained in SRP Section 4.2.

The guidance provided within the SRP forms the basis of the staff's review and ensures that the criteria of 10 CFR 50.46, GDCs 10, 27, and 35 are met.

3.0 TECHNICAL EVALUATION

The FANP Advanced Mark-BW fuel assembly design is an evolution of the FANP Mark-BW fuel assembly design and incorporates new design features including: the TRAPPER bottom nozzle, mid-span mixing grids (MSMGs), a floating intermediate grid design, a quick connect/disconnect top nozzle, and use of M5 material for the cladding, structural tubing, and grids.

This TR extends the use of the fuel design change process defined in EMF-92-116(P)(A), using the design criteria defined within this TR for use in evaluating small changes to the Advanced Mark-BW fuel assembly design. The extension of the EMF-92-116(P)(A) methodology to the Advanced Mark-BW fuel assembly design is accomplished by using the fuel design criteria contained in this TR for the Advanced Mark-BW fuel assembly design while using the compliance demonstration method, nuclear design criteria, and inspections and surveillance methods contained in EMF-92-116(P)(A).

The objectives of this fuel system safety review, as described in SRP Section 4.2, are to provide assurance that (1) the fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs), (2) fuel system damage is never so severe as to prevent control rod insertion when it is required, (3) the number of fuel rod failures is not underestimated for postulated accidents, and (4) coolability is always maintained. A fuel system is "not damaged" when fuel rods do not fail, fuel system dimensions remain within operational tolerances, and functional capabilities are not reduced below those assumed in the safety analyses. Fuel rod failure means that the fuel rod leaks and that the first fission product barrier (the cladding) has been breached. Coolability, which is sometimes termed coolable geometry, means that the fuel assembly retains its rod-bundle geometrical configuration with adequate coolant channels to permit removal of residual heat even after an accident.

3.1 Fuel Assembly Design

The Advanced Mark-BW fuel assembly design is intended for use in Westinghouse three- and four-loop reactors which use a 17 x 17 fuel rod array. The design is based on the Mark-BW fuel assembly design and incorporates some additional features that have been proved through reactor use such as: the TRAPPER bottom nozzle, MSMGs, a floating intermediate grid design, and a low pressure drop quick connect/disconnect top nozzle. The design also uses the M5 advanced alloy which has been previously approved (Reference 7) for cladding, structural tubing and grids. A thorough description and schematic diagrams of the fuel assembly, fuel rod, intermediate grids, low pressure drop quick connect/disconnect top nozzle, guide thimble and instrumentation tubing, MSMGs, debris filter bottom nozzle, and the materials used for each component are provided in Section 3.0 of the TR. Based on the content of the TR, the staff concludes that a satisfactory description of the fuel assembly has been provided for this review.

3.2 Lead Test Assembly (LTA) Program

The LTA program for confirming the irradiation behavior of the Advanced Mark-BW fuel assembly design used four LTAs in locations where the LTAs saw near-peak core power conditions. The LTAs were irradiated for three cycles in the North Anna Unit 1 reactor. During their core residency, two cycles were in high duty locations and during the third cycle the LTAs were placed on the core periphery, a hostile hydraulic environment. Post-irradiation examinations (PIEs) were performed after every irradiation cycle to confirm that the LTAs were operating as predicted. The PIEs performed were appropriate for confirming the performance of the fuel design and the results met expectations; therefore, the LTA performance is acceptable.

3.3 Design Evaluation

The fuel system design bases must reflect these four objectives: (1) the fuel system is not damaged as a result of normal operation and AOOs, (2) fuel system damage is never so severe as to prevent control rod insertion when it is required, (3) the number of fuel rod failures is not underestimated for postulated accidents, and (4) coolability is always maintained. To satisfy these objectives, acceptance criteria are needed for fuel system damage, fuel rod failure, and fuel coolability. The design bases for each criterion remains the same as defined in the Mark-BW fuel assembly (Reference 8).

3.3.1 Fuel System Damage Criteria

The design criteria relating to the fuel system damage should not be exceeded during normal operation including AOOs. Fuel rod failure should be precluded and fuel damage criteria should ensure that fuel system dimensions remain within operational tolerances and that functional capabilities are not reduced below those assumed in the safety analysis. Each damage mechanism listed in SRP Section 4.2 will be reviewed to confirm that the design criteria are not exceeded during normal operation for the Advanced Mark-BW design.

3.3.1.1 Stress

The design criteria for stress are that the stress intensities for Advanced Mark-BW fuel assembly components shall be less than the stress limits based on the American Society of Mechanical Engineers (ASME) Code, Section III criteria (Reference 9). These design criteria are consistent with the acceptance criteria of SRP Section 4.2; therefore, the stress criteria are acceptable for application to the Advanced Mark-BW fuel design.

The stress analyses for the Advanced Mark-BW fuel assembly design were reviewed as part of the staff audit of the TR. The staff confirmed that for the stress analyses calculations, the worst case values in combination with the most limiting cycle conditions and most limiting transients were used to generate the most conservative results for each calculation. This deterministic method to obtain the most limiting stress value provides the most conservative stress value for each fuel assembly component. Positive margin to the design criteria was shown for each of the fuel assembly components; therefore, the staff concludes that the fuel assembly design satisfies the design criteria for design stress.

3.3.1.2 Cladding Strain

The design criterion for strain is that the Advanced Mark-BW fuel rod transient strain (elastic plus plastic) limit should not exceed 1 percent for Condition I and II events. This criterion is intended to preclude excessive cladding deformation during normal operation and AOOs. This design criterion is consistent with the acceptance criteria of SRP Section 4.2; therefore, the strain criterion is acceptable for application to the Advanced Mark-BW fuel design.

The analysis of the cladding strain uses the approved TACO3 code (Reference 10) to determine the cladding strain by evaluating the cladding circumferential changes before and after a linear heat rate (LHR) transient. The 1 percent strain limit corresponds to a transient LHR that is greater than the maximum transient the fuel rod is expected to experience for Condition I and II events. Therefore, the staff concludes that the fuel assembly design criteria for cladding strain are met.

3.3.1.3 Cladding Fatigue

The design criterion for cladding fatigue is that the Advanced Mark-BW maximum fuel rod fatigue usage factor shall not exceed 0.9. This design criterion is consistent with the acceptance criteria of SRP Section 4.2; therefore, this cladding fatigue criterion is acceptable for application to the Advanced Mark-BW fuel design.

The methodology used for determining the cladding fatigue is outlined in Reference 7. The methodology used a fuel rod life of 8 years and a vessel life of 40 years; therefore, the fuel rod will experience 20 percent of the number of transients that the vessel will. The analysis used all the Condition I and II events and one Condition III event to determine the total cladding fatigue usage factor. The maximum fatigue usage factor was determined to be well below the design criteria limit. Since the methodology is consistent with the guidance in SRP Section 4.2 and the maximum fatigue is well below the design criteria limit, FANP has demonstrated that the cladding fatigue acceptance criterion has been met.

3.3.1.4 Fretting

The design criteria for fretting are that the Advanced Mark-BW fuel assembly design shall be shown to provide sufficient support to limit fuel rod vibration and clad fretting wear and that span average cross-flow velocities shall be less than 2 ft/sec. These design criteria are consistent with the acceptance criteria of SRP Section 4.2; therefore, the fretting criteria are acceptable for application to the Advanced Mark-BW fuel design.

Generic mixed core analysis demonstrated that span average cross flows are less than the 2 ft/sec criterion. Therefore, FANP has demonstrated that the Advanced Mark-BW fuel has the ability to meet this criterion.

The Advanced Mark-BW fuel assembly design is an evolution of the Mark-BW fuel assembly design. The in-reactor performance of the Mark-BW fuel assembly design shows that it has positive performance in the fretting arena. This performance is demonstrated through the use of the large number of fuel rods. Similarly, the in-reactor performance of the Advanced Mark-BW LTAs produced positive results even when the LTAs were subjected to the hostile hydraulic environment of the core periphery. FANP also performed out-of-core testing on the Advanced Mark-BW fuel assembly design including a 1000-hour endurance test. The results of the endurance test demonstrated that the fuel rod wear was comparable to other currently approved fuel assembly designs. The staff concludes that the tests and data demonstrate that the Advanced Mark-BW fuel assembly design meets the design criteria for fretting.

3.3.1.5 Oxidation, Hydriding, and Crud Buildup

The design criteria for oxidation, hydriding, and crud buildup are that the Advanced Mark-BW fuel rod cladding best-estimate corrosion shall not exceed 100 microns. These criteria are intended to preclude potential fuel system damage mechanisms. The SRP does not specify specific limits on cladding oxidation and crud, but does specify that their effects should be accounted for in the thermal and mechanical analyses performed for the fuel. FANP accounts for the corrosion based on a database established for the M5 cladding material from in-reactor performance. This is acceptable because it uses realistic data that is representative of the material and burnup limits of the Advanced Mark-BW fuel assembly design.

Based on the data for M5 cladding material under prototypical irradiation conditions, the oxidation and hydrogen pickup rates are well below the criteria limit. Because crud is included as part of the oxidation measurement, the crud is also limited and well within the total acceptable range. Therefore, FANP has demonstrated that the oxidation, hydriding, and crud buildup for the Advanced Mark-BW fuel assembly design have met the acceptance criteria.

3.3.1.6 Fuel Rod Bow

The design criterion for fuel rod bow is that the fuel rod bowing shall be evaluated with respect to the mechanical and thermal-hydraulic performance of the fuel assembly. There is not a specific limit for fuel rod bow specified in SRP Section 4.2; the SRP only requires that rod bow be included in the design analysis.

The FANP methodology for fuel rod bow was approved in Reference 11. The database used to support this methodology was extended in Reference 12. This database is representative of Zircaloy clad fuel. Because M5 cladding grows at a lower rate under irradiation conditions, the database for Zircaloy is conservative relative to the M5 performance. Therefore, the staff concludes that use of this database for predicting the rod bow of M5 clad fuel and continuing use of the penalty generated by the Zircaloy database for M5 fuel is conservative and acceptable for use.

3.3.1.7 Axial Growth

The design criteria for axial growth are that the Advanced Mark-BW fuel assembly-to-reactor internals gap allowance and the fuel assembly top nozzle-to-fuel rod gap allowance shall be designed to provide positive clearance during the assembly lifetime. These design criteria are consistent with the acceptance criteria of SRP Section 4.2; therefore, the axial growth criteria are acceptable for application to the Advanced Mark-BW fuel design.

The axial growth calculations were reviewed as part of the staff audit of the Advanced Mark-BW fuel design. The audit showed that the evaluation of the Advanced Mark-BW fuel design used approved M5 growth models and the worst case scenarios for calculating the clearances. The tolerances were combined in an appropriate manner and treated consistently. The lowest clearance values were obtained at end-of-life (EOL) and in all evaluations, positive clearance remained at EOL under the worst conditions. Therefore, the staff concludes that the Advanced Mark-BW fuel design meets the axial growth acceptance criteria.

3.3.1.8 Fuel Rod Internal Pressure

The design criterion for fuel rod internal pressure is that the fuel system will not be damaged due to excessive internal pressure. Fuel rod internal pressure is limited to that which would cause (1) the diametral gap to increase due to outward creep during steady-state operation, and (2) extensive departure from nucleate boiling (DNB) propagation to occur. These design criteria were approved in Reference 13 and will continue to be valid since the parameters used in the methodology remain unchanged. Therefore, these criteria are acceptable for application to the Advanced Mark-BW fuel design.

The fuel rod internal pressure analysis uses the TACO3 code with the methodology approved in Reference 13. This analysis, performed on a plant-specific basis, includes the use of the most limiting manufacturing variations and a bounding power history for that plant. If the bounding analysis does not meet the fuel rod internal pressure criteria, then on a cycle-specific basis a rod-specific analysis using the actual power history and manufacturing data for that rod can be performed to demonstrate that the internal rod pressure criteria are satisfied. These dual analysis paths using the approved methodology are acceptable for use because they will demonstrate that the fuel rod internal pressure criterion is met.

3.3.1.9 Assembly Liftoff

The design criteria for assembly liftoff are that the Advanced Mark-BW fuel hold down springs must be capable of maintaining fuel assembly contact with the lower support plate during normal operating, Condition I and II events, except for the pump overspeed transient. The fuel assembly shall not compress the hold down spring to solid height for any Condition I and II events. The fuel assembly top and bottom nozzles shall maintain engagement with reactor internals for all Condition I through IV events. These design criteria are consistent with the acceptance criteria of SRP Section 4.2, except for the exclusion of the pump overspeed transient. However, FANP has been previously approved to exclude this transient; therefore, this assembly liftoff criteria are acceptable for application to the Advanced Mark-BW fuel design.

FANP performed the analyses using the approved LYNXT code (Reference 14), and demonstrated that during all conditions considered, except for the pump overspeed transient, the fuel assembly liftoff criteria are met. During the pump overspeed transient, the lift is small and the hold down spring deflection is less than the worst-case normal operating cold-shutdown condition. The hold down spring is not compressed to a solid height for any operating condition. The audit verified that under all operating conditions, the top and bottom nozzles remained engaged with the reactor internals. Therefore, the staff concludes that for the Advanced Mark-BW fuel assembly design, the fuel assembly liftoff criteria are met.

3.3.2 Fuel Rod Failure Criteria

The design criteria relating the fuel rod failure are applied in two ways. When they are applied to normal operation including AOOs, they are used as limits (SAFDLs) since fuel failure should not occur. When they are applied to postulated accidents, fuel failures are permitted and must be accounted for in the fission product releases. Fuel rod failure is defined as the loss of fuel rod hermeticity. Each fuel rod failure mechanism listed in SRP Section 4.2 will be reviewed to confirm that the design criteria are not exceeded during normal operation and is properly accounted for during postulated accidents for the Advanced Mark-BW design.

3.3.2.1 Internal Hydriding

The design criterion for internal hydriding is that the internal hydriding shall be precluded by appropriate manufacturing controls. For the Advanced Mark-BW assembly design, hydriding is prevented by keeping the level of moisture and hydrogenous impurities within the fuel to very low levels. FANP maintains the fabrication level for total hydrogen in the fuel pellets to a level that is lower than the SRP Section 4.2 value of 2 parts per million. This design criterion is consistent with the acceptance criteria of SRP Section 4.2 and is acceptable.

FANP maintains the low hydrogen levels in the fuel rod through manufacturing controls. These controls have resulted in zero failures from internal hydriding for previous fuel designs. Because these controls will remain in place for the Advanced Mark-BW fuel assembly design and the limits are lower than the SRP Section 4.2 values, the design criteria will continue to be met with the Advanced Mark-BW fuel assembly design.

3.3.2.2 Cladding Collapse

The design criterion for cladding collapse is that the predicted creep collapse life of the fuel rod must exceed the maximum expected in-core life. The SRP states that if axial gaps in the fuel pellet column occur due to densification, the cladding has the potential to collapse into a gap. Because of the large local strains that accompany this process, collapsed cladding is assumed to fail. Because the FANP design criterion is consistent with the acceptance criteria of SRP Section 4.2, it is acceptable for application to the Advanced Mark-BW fuel assembly design.

FANP uses their approved creep collapse methodology (Reference 15), to determine the potential for creep collapse of the Advanced Mark-BW fuel assembly design. This methodology uses conservative values to determine the creep collapse life of the fuel rod. Creep collapse is assumed when either the rate of creep ovalization exceeds 0.1 mils/hr or the maximum fiber stress exceeds the unirradiated yield strength of the cladding. Based on these definitions of creep collapse, the creep collapse lifetime was shown to be greater than 62 GWD/MT. Therefore, the Advanced Mark-BW fuel assembly design is adequately designed to prevent creep collapse for a service life up to 62 GWD/MT.

3.3.2.3 Overheating of Cladding

The design criterion for cladding collapse is that for a 95 percent confidence level, DNB will not occur on a fuel rod during normal operation and AOOs. The SRP states that it has been traditional practice to assume that failures will not occur if the thermal margin criteria (i.e., DNB ratio) are satisfied. Because the FANP design criterion is consistent with the acceptance criteria of SRP Section 4.2, it is acceptable for application to the Advanced Mark-BW fuel assembly design.

FANP uses two approved critical heat flux (CHF) correlations in the analysis of DNB occurrence for the fuel (References 16 and 17). These are the BWU-N and BWU-Z CHF correlations. The BWU-N correlation is used for non-mixing vane grids while the BWU-Z correlation is used with enhanced mixing vane grids. These correlations address the types of mixing vane grids used in the Advanced Mark-BW fuel assembly design. Therefore, these correlations are acceptable for use to demonstrate that the design criteria are met during normal operation and AOOs.

In addition, DNB analyses of mixed cores containing Advanced Mark-BW fuel and another vendor's fuel, must be performed using an approved mixed core methodology.

3.3.2.4 Overheating of the Fuel Pellets

The design criteria for overheating of the fuel pellets are that for a 95 percent probability at a 95 percent confidence level, fuel pellet centerline melting shall not occur for normal operation and AOOs. These design criteria are consistent with the acceptance criteria of SRP Section 4.2; therefore, they are acceptable for application to the Advanced Mark-BW fuel assembly design.

SRP Section 4.2 states that this analysis should be performed for the maximum linear heat generation rate anywhere in the core, including all hot spots and hot channel factors, and should account for the effects of burnup and composition on the melting point. FANP uses the TACO3 computer code and fuel melt methodology (Reference 12) to determine the local LHR throughout the fuel rod lifetime that could result in centerline temperature predictions exceeding the limit. The typical generic fuel centerline melt LHR is higher then any expected LHR at beginning-of-life which is the most limiting time of the cycle. Therefore, this analysis demonstrated that for the Advanced Mark-BW fuel assembly design the acceptance criteria are met.

3.3.2.5 Pellet Cladding Interaction (PCI)

There are no generally applicable criteria for PCI failure in SRP Section 4.2. The two criteria that should be applied in accordance with SRP Section 4.2 are that the uniform strain of the cladding should not exceed 1 percent and fuel melting should be avoided. Since both of these criteria were addressed previously in this safety evaluation (SE), the criteria for PCI are satisfied and acceptable for the Advanced Mark-BW design.

3.3.2.6 Cladding Rupture

There is not a specific design limit associated with cladding rupture other than the requirements in 10 CFR 50.46, Appendix K. The cladding rupture correlation and supporting data were reviewed and approved for LOCA emergency core cooling system (ECCS) analyses in Reference 7. Because this correlation was developed specifically for use in analyzing M5 cladding, the use of this correlation will provide the appropriate cladding rupture evaluations for the Advanced Mark-BW fuel assembly design under accident conditions.

3.3.3 Fuel Coolability

For postulated accidents in which severe damage might occur, core coolability must be maintained as required by GDC 27 and 35. Coolability, or coolable geometry, has traditionally implied that the fuel assembly retains its rod bundle geometry with adequate coolant channels to permit the removal of residual heat.

3.3.3.1 Cladding Embrittlement

To meet the requirements of 10 CFR 50.46, as it relates to LOCA, acceptance criteria of 2200°F on peak cladding temperature and 17 percent on maximum cladding oxidation must be met. FANP demonstrated through high temperature oxidation and quenching tests that the M5 cladding can meet these limits. The data and analysis to support this conclusion were reviewed and approved in Reference 7. Further, Reference 7 concluded that the Baker-Just correlation is conservative for determining high temperature M5 oxidation for LOCA analysis and; therefore, is acceptable for LOCA ECCS analyses. Since the Baker-Just correlation is conservative and is required in accordance with 10 CFR 50.46 Appendix K, this criteria will be met without any modification needed to the approved LOCA ECCS codes.

3.3.3.2 Violent Expulsion of Fuel

In severe reactivity insertion accidents (RIAs), such as a rod ejection event, the large and rapid deposition of energy in the fuel can result in melting, fragmentation, and dispersal of fuel. To limit the effects of an RIA, Regulatory Guide 1.77 (Reference 18), recommends that the radially averaged deposition at the hottest axial location be limited to 280 cal/g. Reference 7 reviewed and approved the use of M5 cladding and found that the use of M5 cladding has little impact on fuel expulsion and failure. Because the use of M5 will not impact the RIA analysis, this criteria will be met without any modification needed to the approved RIA analysis methodology.

3.3.3.3 Fuel Rod Ballooning

To meet the requirements of 10 CFR 50.46, as related to the evaluation of ECCS performance during accidents, burst strain and flow blockage caused by ballooning of the cladding must be accounted for in the analysis of the core flow distribution. FANP developed new ballooning and flow blockage models for M5 cladding which were reviewed and approved in Reference 7. Since these models were developed specifically for use in analyzing M5 cladding, the use of these models will provide the appropriate fuel rod ballooning for the Advanced Mark-BW fuel assembly design.

3.3.3.4 Fuel Assembly Structural Damage from External Forces

Earthquakes and postulated pipe breaks in the reactor coolant system would result in external forces on the fuel assembly. During these events, fuel system coolability should be maintained and damage should not be so severe as to prevent control rod insertion when required. The design criteria for fuel assembly structural damage from external forces are divided into three categories:

- Operating Basis Earthquake (OBE) – Allow continued safe operation of the fuel assembly following an OBE event by ensuring the fuel assembly components do not violate their dimensional requirements.

- Safe Shutdown Earthquake (SSE) – Ensure safe shutdown of the reactor by maintaining the overall structural integrity of the fuel assemblies, control rod insertability, and a coolable geometry within the deformation limits consistent with the ECCS and safety analysis.

- LOCA or SSE+LOCA – Ensure safe shutdown of the reactor by maintaining the overall structural integrity of the fuel assemblies and a coolable geometry within deformation limits consistent with the ECCS and safety analyses.

These design criteria are consistent with SRP Section 4.2 guidance; therefore, they are acceptable for application to the Advanced Mark-BW fuel assembly design.

FANP used the methodology in References 19 and 20 to perform generic evaluations of the structural damage from external forces. These analyses considered the horizontal and vertical impacts on the fuel assembly. These analyses included generic evaluations of the impact on the Advanced Mark-BW fuel assembly design when it is located in a mixed core. Various core loading patterns and locations in the core were utilized for the mixed core analysis impact. The results showed that the combined loads on the Advanced Mark-BW fuel assembly were small enough that coolable geometry is always maintained. The analyses results demonstrated that coolable geometry can be maintained under all the analyzed conditions; therefore, FANP demonstrated that the acceptance criteria are met.

4.0 CONDITIONS AND LIMITATIONS

The staff approves use of this TR subject to the following conditions:

(1) This fuel assembly design is approved for use with LEU fuel, which has been enriched to less than or equal to 5 percent.

(2) The Advanced Mark-BW fuel assembly design is licensed for a maximum fuel rod burnup of 62,000 MWD/MT.

5.0 CONCLUSION

The NRC staff reviewed the acceptance criteria and generic and proposed analysis methodology presented by FANP in TR BAW-10239(P), Revision 0, "Advanced Mark-BW Fuel Assembly Mechanical Design Topical Report," and determined that the criteria and proposed analysis methods are performed in accordance with the guidance provided in SRP Section 4.2. The staff finds the criteria and proposed analysis methods outlined in this TR acceptable based on the determinations provided in the technical evaluation section of this SE and concludes that the TR is acceptable for referencing by licensees. Any information contained in the TR and the supplemental letters (References 1 through 4), that is not explicitly approved in this SE has not been reviewed by the staff and is not accepted.

Therefore, on the basis of the above review and justification, the staff concludes that the FANP Advanced Mark-BW fuel assembly design is acceptable for use in Westinghouse three- and four-loop design reactors which use a 17 x 17 fuel rod array with LEU fuel subject to the conditions included in this SE.

6.0 REFERENCES

1. Letter from James Mallay, Framatome ANP to the USNRC, "Request for Review of BAW-10239(P), Revision 0, “Advanced Mark-BW Fuel Assembly Mechanical Design Topical Report'," April 30, 2002. (ADAMS Accession No. ML041700438.)

2. Letter from James Mallay, Framatome ANP to the USNRC, "Response to RAI to Topical Report BAW-10239(P)," May 9, 2003. (ADAMS Accession No. ML031330112.)

3. Letter from James Mallay, Framatome ANP to the USNRC, February 9, 2004. (ADAMS Accession No. ML040430211.)

4. Letter from James Mallay, Framatome ANP to the USNRC, March 18, 2004. (ADAMS Accession No. ML040820700.)

5. NUREG-0800, Standard Review Plan, Section 4.2, "Fuel System Design," Revision 2, U.S. Nuclear Regulatory Commission, July 1981.

6. EMF-92-116(P)(A), Revision 0, "Generic Mechanical Design Criteria for PWR Fuel Designs," February 1999.

7. BAW-10227-P-A, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel," February 2000.

8. BAW-10172P, "Mark-BW Mechanical Design Report," July 1988.

9. American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1992.

10. BAW-10162-P-A, "TACO3 Fuel Pin Analysis Computer Code," October 1989.

11. BAW-10147-P-A, Revision 1, "Fuel Rod Bowing in Babcock & Wilcox Fuel Designs," May 1983.

12. BAW-10186-P-A, Revision 1, Supplement 1, "Mark-BW Extended Burnup," November 2001.

13. BAW-10183-P-A, "Fuel Rod Gas Pressure Criterion (FRGPC)," July 1995.

14. BAW-10156-P-A, Revision 1, "LYNXT: Core Transient Thermal-Hydraulic Program," August 1993.

15. BAW-10084-P-A, "Program to Determine In-Reactor Performance of BWFC Fuel Cladding Creep Collapse," July 1995.

16. BAW-10199-P-A, "The BWU Critical Heat Flux Correlations," December 1994.

17. BAW-10199-P-A, Addendum 2, "Application of the BWU-Z CHF Correlation to the Mark-BW17 Fuel Design with Mid-Span Mixing Grids," November 2000.

18. Regulatory Guide 1.77, "Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors," May 1974.

19. BAW-10133-P-A, "Mark-C Fuel Assembly LOCA-Seismic Analyses," June 1986.

20. BAW-10133-P-A, Revision 1, Addendum 1, "Mark-C Fuel Assembly LOCA-Seismic Analyses," October 2000.

Attachment: Resolution of Comment

Principal Contributor: U. Shoop

Date: July 1, 2004

RESOLUTION OF COMMENT

ON DRAFT SAFETY EVALUATION FOR BAW-10239(P), REVISION 0,

"ADVANCED MARK-BW FUEL ASSEMBLY MECHANICAL DESIGN TOPICAL REPORT”

By letter dated April 23, 2004, Framatome ANP provided comment on the draft safety evaluation (SE) for BAW-10239(P), Revision 0, "Advanced Mark-BW Fuel Assembly Mechanical Design Topical Report." The following is the staff's resolution of the comment.

1. FANP Comment: Delete the third condition in the Introduction section and the Conditions section. Framatome ANP believes this condition is unnecessary, and provided additional information via phone to support why this condition is inappropriate.

   NRC Action: This comment was fully adopted. Condition 3 was deleted.

Additional changes that were made, as a result of incorporating FANP’s comment:

1. In Section 1.0, Introduction, the entire second paragraph was deleted.

2. In Section 3.0, Technical Evaluation, the entire third paragraph was deleted.

3. In Section 3.3.1.8, Fuel Rod Internal Pressure, second to last sentence, "... it is fuel design-independent," was replaced with "... the parameters used in the methodology remain unchanged."

4. In Section 3.3.1.9, Assembly Liftoff, first paragraph, last sentence, "... received previous approval for this particular model to exclude this transient," was replaced with "... has been previously approved to exclude this transient."

5. In Section 3.3.2.3, Overheating of Cladding, the second paragraph, last sentence, "...meet the design criteria and are acceptable for use," was replaced with "... are acceptable for use to demonstrate that the design criteria are met during normal operation and AOOs."

6. In Section 3.3.2.3, Overheating of Cladding, a new paragraph was added at the end of the section.

7. In Section 3.3.2.4, Overheating of the Fuel Pellets, second paragraph, second sentence, the following was added: "... and fuel melt methodology (Reference 12) ..." in the middle of the sentence.

8. In Section 5.0, Conclusion, the entire second paragraph was deleted.

ATTACHMENT