Supplement 1 to

BAW-10186 Revision 1
(43-10186-02)

Mark-BW Extended Burnup

by

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Acknowledgement

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1.0 Introduction

Framatome ANP, Inc. manufactures Mark-BW and Mark-B fuel designs that are currently licensed to fuel rod burnups of 60,000 MWd/mtU and 62,000 MWd/mtU respectively (References 1 and 2). Framatome ANP, Inc. is requesting an extension of its Mark-BW product to 62,000 MWd/mtU. This document is a Supplement to Reference 1 (BAW-10186 Revision 1) for the Mark-BW designs. This document provides the justification for the use of the Mark-BW design with M5™ cladding to 62,000 MWd/mtU. The approval of this Supplement will supercede the SER restrictions on burnup in Reference 1 (BAW-10186 Revision 1) and Reference 2 (BAW-10227 Revision 0) for the Mark-BW designs.

The extension to 62,000 MWd/mtU is requested for M5™ clad in structures made from either Zr-4 or M5™. Fuel assembly structure materials may be Zr-4 or M5™; i.e., guide tubes, instrument tube, spacer grids and other applicable components. However, since the Mark-BW fuel has a higher operating temperature than Mark-B fuel leading to an increased clad corrosion rate, fuel rod cladding fabricated in Zr-4 is excluded from this extension request.

2.0 Summary

The justification for this extension of the Mark-BW fuel rod burnups to 62,000 MWd/mtU is based on the similarity to the Mark-B product and the additional data available since the submittal of References 1 and 2. These two items reduce the degree of extrapolation of the models with respect to burnup. In addition, commitments to future Post Irradiation Examination (PIE) campaigns will further increase the database for both the Mark-B and Mark-BW fuel designs. The extended burnup capabilities of Framatome ANP Inc.'s Mark-BW design have been evaluated based on peak fuel rod burnups of 62,000 MWd/mtU. The methods and data described or referenced in this report support plant specific licensing to this burnup.

2.1 Fuel Rod Burnup

Table 2.1-1 summarizes fuel rod burnup for the Mark-BW fuel from the time of the original topical (1996) to the present time. In addition, Figure 2.1-1 depicts the fuel rod burnup distribution for high burnup Mark-BW fuel at the time of the original topical reports (References 1 and 2) and the present time, respectively. A significant amount of data has been gathered since the original topical reports were submitted.

Table 2.1-1
Fuel Rod Burnup for High Burnup Mark-BW Fuel

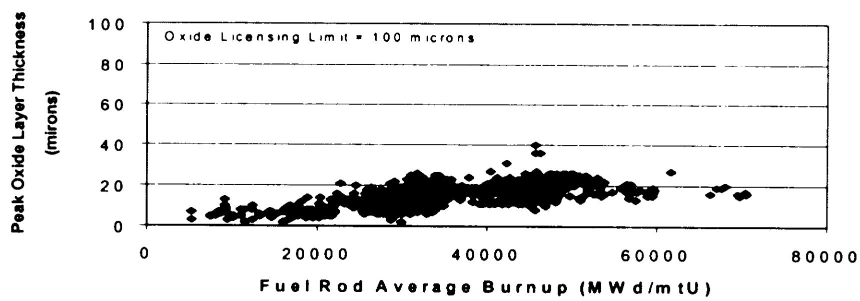
2.2 Key Updated PIE Measurements

Two key updated PIE measurements are fuel rod oxide and fuel assembly growth.

2.2.1 Fuel Rod Oxide

Figure 2.2-1 depicts the corrosion performance of alloy M5™ fuel rod cladding. As shown in the figure, the oxide thickness at 62,000 MWd/mtU is well below the 100-μm best-estimate licensing limit. See Section 4.4 for further discussion.

Figure 2.2-1
Corrosion of Framatome ANP M5 Cladding



2.2.2 Fuel Assembly Growth

Fuel assembly growth measurements to date for both the Mark-B and Mark-BW fuel designs are plotted in Figure 2.2-2. As can be seen from this figure, a significant amount of fuel assembly growth data has been gathered since the original topical. Currently the all Zr-4 fuel assembly designs (clad and guide tubes) are limited by fuel assembly growth. As established in Reference 2, the all M5™ and the M5™ Clad upper tolerance limits (UTLs) are set as [80%] of all Zr-4. The growth data for the all M5™ design presented in Figure 2.2-2 clearly is within this UTL limit.

Figure 2.2-2
Framatome ANP FA Growth

[ ]

2.3 Commitments to Planned Examinations

References 1 and 2 both have SER requirements to collect additional PIE data as a condition of approval. Two PIE campaigns are planned for the Mark-BW fuel design. These are at North Anna 1 at the end of 2001 and at North Anna 2 in 2004. Four advanced Mark-BW LTAs at North Anna 1, cycle 15 have finished their third cycle of irradiation. Following cycle 15, PIE data will be collected to verify the performance of these LTAs that contain M5™ fuel rods and guide tubes and other advanced features such as mid span mixing grids and a quick disconnect top nozzle. One of these assemblies will be reinserted into North Anna 2 for an additional cycle of irradiation beyond the current Mark-BW licensed burnup limits. The fourth cycle of irradiation for this LTA is expected to achieve rod burnups in excess of 70,000 MWd/mtU. PIE campaigns are also scheduled for Mark-B fuel at Three Mile Island-1 (2001, 2003), Davis Besse (2002, 2004, 2006), and Oconee 2 (2002). These plans are contingent on utility approval. However, the commitments in Section 5.0 remain in effect.

3.0 Data Sources

Table 3.0-1 below lists the major fuel performance inspections performed on irradiated fuel for both the Mark-B and Mark-BW fuel assembly designs in the United States. The last three rows in the table represent the inspection of a larger number of fuel assemblies experiencing typical modern fuel cycles. The assemblies measured represent the highest burnup assemblies in those cycles.

Table 3.0-1 Major Fuel Performance Programs

Program	Plant	Completed Irradiation Cycles	Max Fuel Rod Burnup GWd/mtU	Post Irradiation Examinations
Mark-B	Oconee 1	5[a]	[ ]	Poolside & Hotcell
Mark-BEB	ANO 1	4[b]	[ ]	Poolside & Hotcell
Mark-GdB	Oconee 1	4[c]	[ ]	Poolside & Hotcell
Mark-BZ	Oconee 1	3[d]	[ ]	Poolside
Mark-BAB	SMUD	3[e]	[ ]	Poolside
Mark-B	Oconee 2	3[f]	[ ]	Poolside & Hotcell
Mark-C	Oconee 2	3[g]	[ ]	Poolside
Mark-B, Pathfinder	Oconee 1	3[h]	[ ]	Poolside
Mark-BW15 Zircaloy LTAs	Conn Yankee	3[i]	[ ]	Poolside
Mark-BW17 Advanced Clad	McGuire 1	2[j]	[ ]	Poolside
Mark-BW17 LAs	McGuire 1	3[k]	[ ]	Poolside & Hotcell
Mark-BW17 Special Clad	McGuire 1	3[l]	[ ]	Poolside
Mark-BW M5™ LTAs	North Anna 1	3[m]	[ ]	Poolside
Mark-BW17	Catawba 2	3[n]	[ ]	Poolside
Mark-B	TMI 1	3[o]	[ ]	Poolside
Mark-B	TMI 1	3[p]	[ ]	Poolside

(a) Base FA design irradiated to high burnup for evaluation and modeling as part of a B&W/DOE/Duke Power joint program.

(b) LTAs of an advanced, extended-burnup design.

(c) An extended burnup fuel assembly design with selected fuel rods loaded with Gadolinia (Gd_2O_3 - UO_2) fuel pellets as an integral burnable poison.

(d) LTAs utilizing Zr-4 intermediate spacer grids for low absorption.

(e) LTAs containing axially blanketed fuel columns.

(f) Fuel assemblies examined poolside, and selected fuel rods pulled and examined in a hotcell as part of a joint BWFC/EPRI/Duke Power fuel failure investigation.

(g) Mark-C LTAs with 17 x 17-fuel rod array, two of these four LTAs are reconstitutable.

(h) Pathfinder LTA with advanced Zr-4 cladding materials.

(i) Four LTAs using Zr-4 clad fuel rods to replace stainless steel clad fuel rod assemblies.

(j) One Lead Assembly (17x17, Mark-BW17 LA) with six different advanced cladding alloys within the Zr-4 specification.

(k) Three Lead Assemblies (17x17, Mark-BW17 LA).

(l) Two LAs with twelve advanced cladding alloys, six are within the Zr-4 specification, six are outside of the specification, e.g. non Zr-4 alloys.

(m) Four Lead Assemblies (17x17, Mark-BW/M5™).

(n) Six production Mark-BW fuel assemblies irradiated three typical cycles.

(o) Ten production Mark-B fuel assemblies irradiated 1, 2, or 3 typical cycles.

(p) Eleven production Mark-B fuel assemblies irradiated 1, 2, or 3 typical cycles.

The database for M5™ cladding in the U.S. is shown in Table 3.0-2 below. This data represents a small fraction of the data gathered on M5™ worldwide. The U.S. data fits well within the data gathered worldwide, which demonstrates that the cladding performs as well in U.S. cycles. This data will be discussed in greater depth in Section 4.4.

Table 3.0-2 U.S. M5™ Fuel Rod Demonstrations

Reactor	***Fuel Assembly***	***Plant Cycles***
McGuire-1	NJ05LC	8, 9, 10
	NJ05LD	8, 9, 10
North Anna-1	NJ092P	13, 14, 15
	NJ092R	13, 14, 15
	NJ092T	13, 14, 15
	NJ092V	13, 14,15
TMI-1	NJ07VX	11, 12, 13
	NJ07VY	11, 12, 13

Note: This table does not include Framatome ANP Inc.'s first full batches of M5™ clad fuel at Davis Besse and Oconee since a full first cycle of operation is not complete. A fourth irradiation cycle is planned for one of the four North-Anna assemblies. Four pins are from one of the TMI assemblies are planned for reinsert for a fourth cycle in TMI cycle 14.

The many similar features of the Mark-B and Mark-BW fuel designs allow the results of Mark-B PIE campaigns to be used to support justification for the Mark-BW burnup extension. Both designs are similarly constructed using floating grids, fuel rods seated on the bottom nozzle and like materials. The fuel rod support systems [(grid to fuel rod contact, soft stop deflection) are similar] for both designs. End grids for both designs monometallic and fabricated with Inconel 718. The intermediate grids are monometallic in Zr-4 or M5™. Tables 3.0-3 and 3.0-4 list updated fuel assembly parameters for the Mark-B and Mark-BW fuel assembly designs, respectively.

The power densities of the Mark-B and Mark-BW fuel are in the same range. The range of operating pressures and temperatures for plants using Mark-B and Mark-BW fuel are similar with the Mark-BW plants typically operating at the higher end of the temperature range. In order to minimize corrosion concerns associated with the higher temperature for the Mark-BW fuel, Framatome ANP will use only fuel with M5™ cladding in those applications. The similar metal-to-water ratios of the two designs make them equivalent from a nuclear standpoint. The mechanical, thermal-hydraulic, and nuclear similarities of the Mark-B and Mark-BW fuel designs support the use of Mark-B data to justify the Mark-BW burnup extension to 62,000 MWd/mtU. Tables 3.0-3 and 3.0-4 list updated fuel assembly parameters for the Mark-B and Mark-BW fuel assembly designs, respectively.

Table 3.0-3 Typical Framatome ANP, Inc. Fuel Assembly Parameters †
(B&W Reactor Systems)

Assembly Designation	Mark-B
Fuel Rod Array	15x15
Holddown Spring	Helical Coil Spring or Multiple Leaf Spring
Cladding Material	Zr-4, M5™
Guide Tube Material	Zr-4, M5™
Assemblies per Core	177
Fuel Rods per Assembly	208
Control Rod/Guide Tube/Instrument Tube Locations Per Assembly	17
Debris Protection Feature	Solid Lower End Plug*
Rod Pitch, mm (inch)	14.4 (0.568)
Fuel Rod Length, cm (inch)	[ ]* [ ]
Active Fuel Height, cm (inch)	360.2* (141.8)
Plenum Length, cm (inch)	[ ]* [ ]
Fuel Rod O.D., mm (inch)	10.92* (0.430)
Cladding I.D., mm (inch)	[ ] [ ]
Cladding Thickness, mm (inch)	[ ] [ ]
Diametrical Gap, microns (mils)	[ ] [ ]
Fuel Pellet O.D., mm (inch)	[ ] [ ]
Fuel Pellet Density, % TD	[ ]
Average LHGR, W/cm (kW/ft)	203 (6.20)
System Pressure, MPa (psia)	15.2 (2200)
Core Inlet Temp., °C (° F)	292.07 (557.7)
Core Outlet Temp., °C (° F)	315.7 (600.3)

† Designs, materials and dimensions are representative of those used to date. Alternates may be used if they are demonstrated to meet the burnup requirements.

* Other Options Available.

** Design has used both densities.

Table 3.0-4 Typical Framatome ANP, Inc. Fuel Assembly Parameters †
(Westinghouse Reactor Systems)

Assembly Designation	Mark-BW17
Fuel Rod Array	17x17
Holddown Spring	Leaf Springs
Cladding Material	Zr-4, M5™
Guide Tube Material	Zr-4, M5™
Assemblies per Core	193 (157)
Fuel Rods per Assembly	264
Control Rod/Guide Tube/Instrument Tube Locations per Assembly	25
Debris Protection Feature	Filter Lower End Fitting*
Rod Pitch, mm (inch)	12.6 (0.496)
Fuel Rod Length, cm (inch)	[ ] [ ]
Active Fuel Height, cm (inch)	365.8 (144.0)]
Plenum Length, cm (inch)	[ ] [ ]
Fuel Rod O.D., mm (inch)	9.50 (0.374)
Cladding I.D., mm (inch)	[ ] [ ]
Cladding Thickness, mm (inch)	[ ] [ ]
Diametrical Gap, microns (mils)	[ ] [ ]
Fuel Pellet O.D., mm (inch)	[ ] [ ]
Fuel Pellet Density, % TD	[ ]
Average LHGR, W/cm (kW/ft)	178 (5.43)
System Pressure, MPa (psia)	15.5 (2250)
Core Inlet Temp., °C (° F)	294.2 (561.6)
Core Outlet Temp., °C (° F)	326.7 (620)

† Designs, materials and dimensions are representative of those used to date. Alternates may be used if they are demonstrated to meet the burnup requirements.

* Other Options Available.

** Design has used both densities.

4.0 Fuel Rod and Assembly Models

The parameters in Chapter 4 of the SRP (Reference 3) that are significantly impacted by a burnup extension are addressed in this Section.

4.1 Fuel Rod and Fuel Assembly Growth

There are three options to consider:

All Zr-4	- Zircaloy-4 clad and guide tubes.
M5™ Clad	- M5™ clad and Zr-4 guide tubes.
All M5™	- M5™ clad and guide.

4.1.1 Fuel Assembly Growth

Fuel assembly (FA) growth must be controlled in order to prevent the fuel assembly structure from extending to the point of contact on the top nozzle structure and the core plate. The fuel assembly growth for both Framatome ANP Inc.'s Mark-B and Mark-BW fuel designs is plotted in Figure 4.1.1-1. A significant amount of fuel assembly growth data has been gathered since the original topical reports were submitted. Owing to the axial similarity of the fuel designs, the Mark-B and Mark-BW databases can be combined into a single database. Fuel assembly growth is highly material dependent and therefore Zr-4 and M5™ structures are plotted separately. The UTL on assembly growth for the M5™ clad and the all M5™ cases are established by [ ] of all Zr-4 case (Reference 2). This M5™ assembly growth UTL is clearly conservative with respect to the data presented in the graph. A margin greater than [ ] for closure of the fuel assembly to core plate gap exists for current FA design lengths using the conservative M5™ assembly growth UTL. Greater than [ ] margin exists with a conservative extrapolation of the North Anna first cycle growth value to 62,000 MWd/mtU.

Figure 4.1.1-1
Framatome ANP FA Growth

4.1.2 Shoulder Gap Closure

Framatome ANP, Inc. introduced the shoulder gap closure model in Figure 3-8 of Reference 2 as an alternative to computing it based on combined fuel assembly and fuel rod models. An updated fuel assembly shoulder gap closure curve for a Zr-4 structure is given in Figure 4.1.2-1. This model is conservative since it is based on the maximum shoulder gap closure per fuel assembly measured in the PIEs. In this instance also, owing to the axial similarity of the fuel designs, the Mark-B and Mark-BW databases can be combined into a single database. Shoulder gap is well behaved with respect to burnup and is exhibited in Figure 4.1.2-1. Framatome ANP Inc.'s existing all Zr-4 designs have more than [ ] inches of Beginning of Life (BOL) shoulder gap. This results in greater than [ ] margin for a Zr-4 design at 62,000 MWd/mtU.

In addition, the model in Figure 4.1.2-1 is conservative for the M5™ clad case (M5™ clad and Zr-4 guide tubes) since it has been shown (Reference 2) that M5™ fuel rods have lower growth than Zr-4 which leads to a larger shoulder gap.

Figure 4.1.2-1
Framatome ANP Combined Zr-4 Shoulder Gap Closure

[ ]

For the case of the all M5™ design the use of fuel rod UTLs and fuel assembly LTLs will be maintained until such time that a shoulder gap model can be developed. A shoulder gap model will be developed and used when sufficient data have been gathered. The current M5™ fuel rod model for Mark-BW is presented in Figure 4.1.2-2 along with a sample shoulder gap model developed in accordance with the concepts given in Reference 2 (fuel assembly growth is [ ] of that of a Zr-4 structure, fuel rod growth is per fuel rod model).

Figure 4.1.2-2
Framatome ANP M5 Shoulder Gap Closure

[ ]

Actual shoulder gap measurements for Framatome ANP Inc.'s M5™ LTAs, which recently completed their 3rd cycle of irradiation at Dominion Generation's North Anna Plant are also plotted in Figure 4.1.2-2. The data here are after 2 cycles of irradiation and shows that the shoulder gap model for the M5™ design computed this way is slightly non-conservative. This is due to the fact that the fuel assemblies in North Anna are experiencing zero growth at the fuel assembly level. However, even with [ ], there is over [ ] margin at a burnup of 62,000 MWd/mtU. Ample shoulder gap margin exists for burnup extension to 62,000 MWd/mtU for the Mark-BW design. The all M5™ case is the most limiting since the use of Zr-4 guide tubes (M5™ clad or all Zr-4 cases) will lead to larger shoulder gaps due to higher FA growth.

4.2 Fuel Assembly Structure Oxidation

Although the primary concern with the oxidation rate of Zr-4 lies in its effect on fuel rods, structural tubing must also be considered as fuel assembly burnup limits are extended. Zr-4 guide tubes and instrument tubes differ from fuel rod cladding in two important ways - metallurgical structure and service environment. Concerning structure, Zr-4 fuel rod cladding is in the stress-relieved and annealed condition (SRA) whereas structural tubing is supplied in the recrystallized condition (RXA). Experience has shown that the oxidation rate of Zr-4 is strongly dependent on temperature and that the RXA material has a lower initial oxidation rate than the SRA fuel rod cladding. With respect to the service environment of structural tubing, it differs in two important ways from fuel rod cladding - temperature and exposed surface area. Structural tubing operates cooler than fuel rod cladding because it is essentially at the same temperature as that of the bulk primary coolant. Guide tubes and instrument sheaths are exposed to coolant on both the ID and OD surfaces and oxidation proceeds at approximately the same rate on each.

Guide tube oxidation data is measured in fuel assembly post irradiation examinations (PIE). The oxidation data presented in Figure 4.2-1 illustrates three important points concerning the oxidation kinetics of Zr-4 structural tubing. First, the Mark-B and Mark-BW data are seen to be similar in their evolution with burnup even though Mark-BW fuel typically operates at higher temperatures than Mark-B. Secondly, the oxidation layer thickness is on the order of one-third of that of fuel rod oxidation at higher burnup. This is because of the strong correlation of oxidation rate with temperature for Zr-4. The cooler operating structural tubing is oxidizing at a lower rate than the hotter fuel rods. Lastly, the effects of oxide thickness of the Mark-B and Mark-BW structural tubes is considered in fuel assembly structural analysis when establishing design limits and operating margins.

Many years of operational experience with Zr-4 structural tubing has resulted in no failures and the PIE data suggests that none will occur at extended burnup to 62,000 MWd/mtU. Structural margins are greater for M5™ given the lower oxidation rate for M5™ and the similar material properties of the two alloys.

Figure 4.2.1
Framatome ANP Zircaloy-4 GT Oxide

[ ]

4.3 Spacer Grid Irradiation Growth

The data for Mark-B and Mark-BW grid growth can be combined due to the similarity of the designs. Grid growth is plotted in Figure 4.3-1 as a function of burnup for grid 2. Grid 2 is the top most intermediate grid, and due to the higher temperature in this region, it has been shown to have the greatest growth. The data follow a linear relation with burnup. The result of grid growth is to reduce the inter-assembly and assembly-baffle plate gaps. Framatome ANP Inc.'s evaluation of the available gap at 62,000 MWd/mtU results in sufficient margin to prevent a "solid" core condition.

Figire 4.3-1
Framatome ANP Grid Growth

[ ]

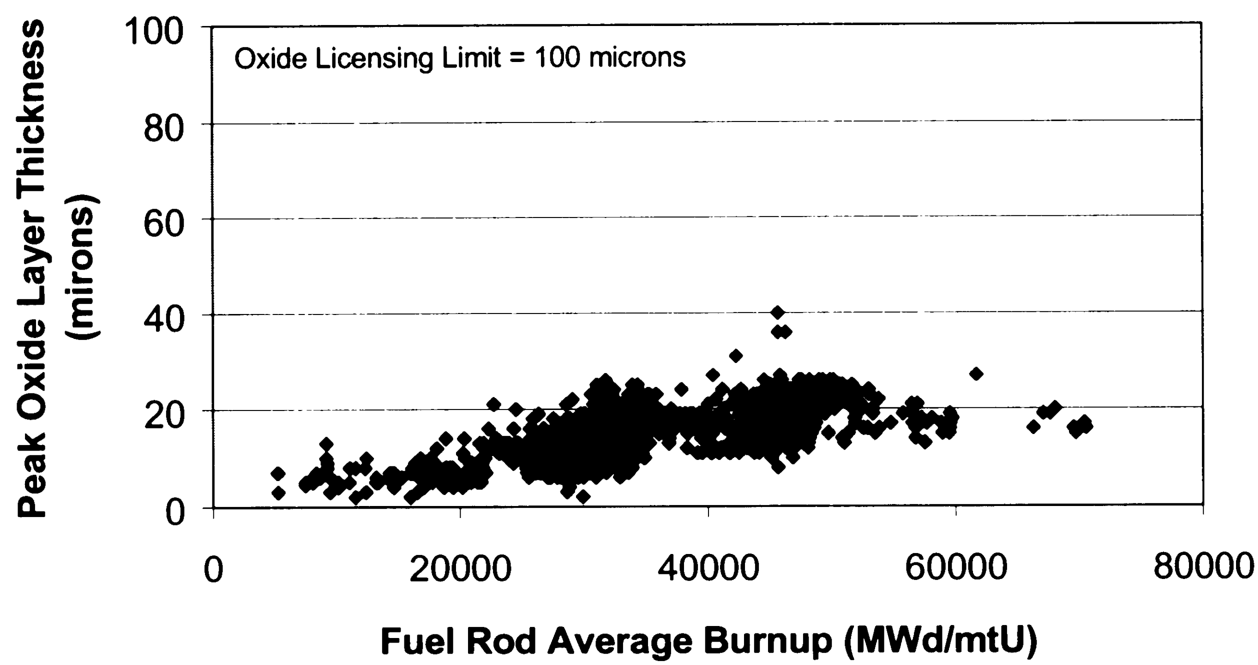
4.4 Oxidation, Corrosion and Crud

Figure 4.4-1 shows the corrosion performance of alloy M5™ fuel rod cladding. Maximum oxide thickness, measured in the highest temperature and fluence region of the fuel assembly (second spacer-grid span from the top), is plotted as a function of fuel rod burnup.

The well-known trend of increasing data scatter with burnup for Zr-4 is not observed for alloy M5™. This behavior is indicative of a lower sensitivity of the alloy's oxidation kinetics to various irradiation conditions, including reactor power histories and differences in operating conditions from one reactor to another. A reduction in maximum oxide thickness by a factor of three to four is evident at the highest achieved burnups. The margin to the 100-μm (micron) cladding licensing limit is significantly increased. Because crud formation is a result of clad oxidation, its production will be significantly reduced also.

Several years of PWR irradiation history on alloy M5™ fuel rod cladding indicates that the M5™ alloy provides the high design margins necessary for superior performance at extended burnups.

Figure 4.4-1
Corrosion of Framatome ANP M5 Cladding



4.5 Fuel Rod Bowing

The fuel rod criteria in Reference 1 (saturation of fuel rod bow with burnup) remain applicable with the use of M5™ cladding. In addition M5™ material properties were addressed in Reference 2. Framatome ANP, Inc. restates its commitment to obtaining additional fuel rod bow data. Fuel rod bow measurements are planned for the Mark-BW M5™ LTAs that have recently completed 3 cycles of irradiation at Dominion Generation's North Anna plant.

4.6 Control Rod Drop Time

Since Framatome ANP Inc.'s Mark-BW Fuel Assembly has a dashpot integral to the guide thimbles, its design is unique relative to the Mark-B design. Therefore, only control rod drop time data from Mark-BW plants are presented. The technical specification limit for this parameter is 2.2 seconds to start of dashpot. A control rod in a position occupied by Mark-BW fuel has never exceeded this limit. Control rod drop time to start of dashpot vs. burnup is plotted for four plants fueled with Framatome ANP Inc.'s Mark-BW fuel assemblies in Figures 4.6-1 through 4.6-4 below:

Figure 4.6-1
Time to Dashpot - Catawba 1

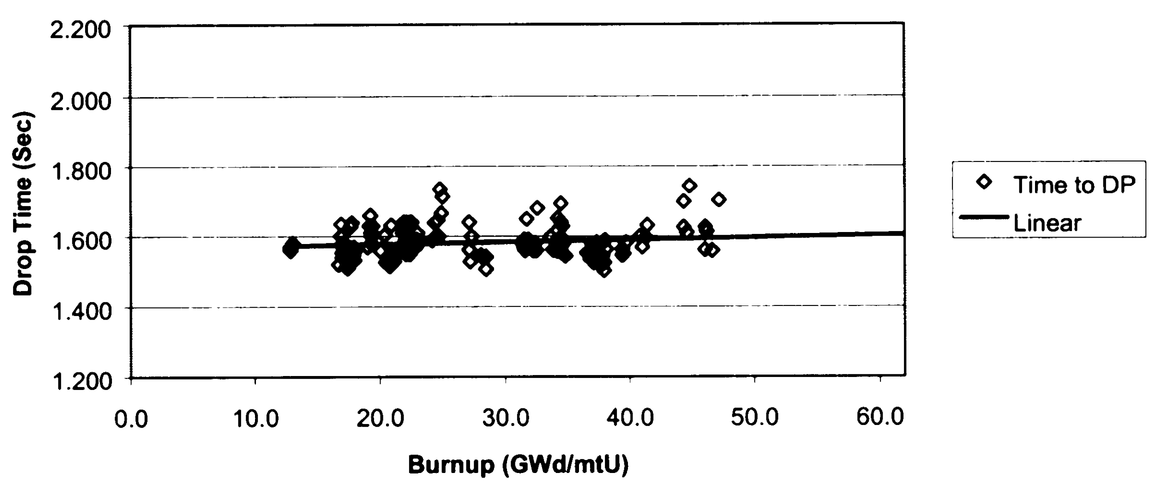


Figure 4.6-2
Time to Dashpot - Catawba 2

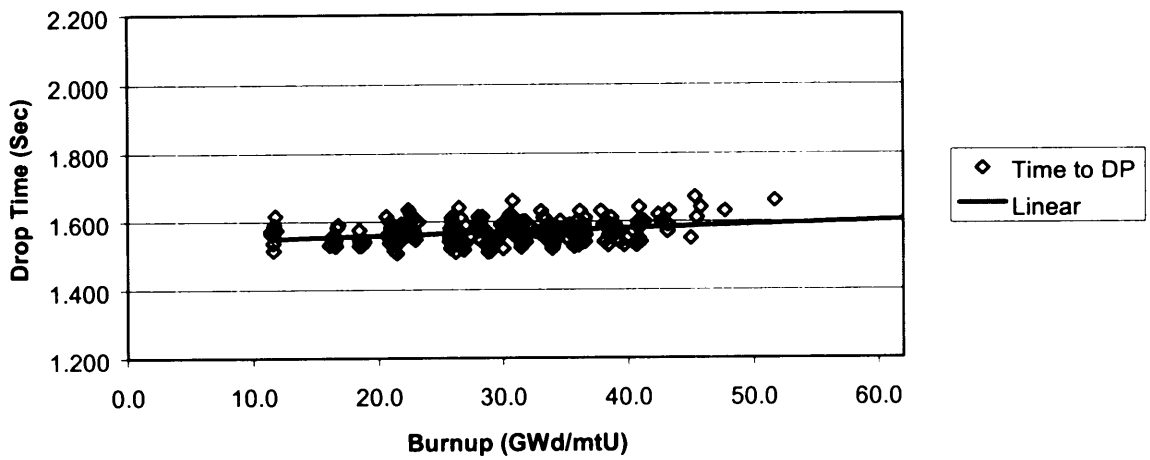


Figure 4.6-3
Time to Dashpot - McGuire 1

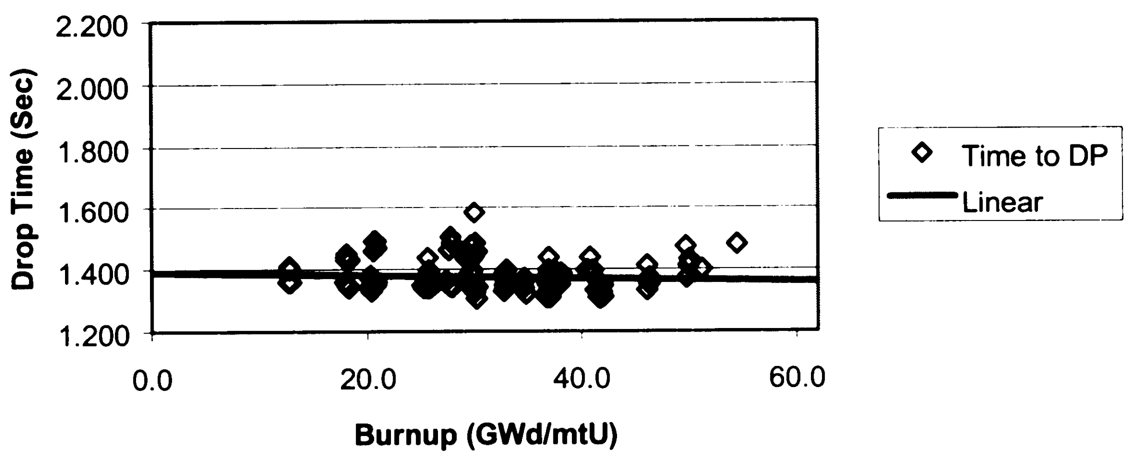
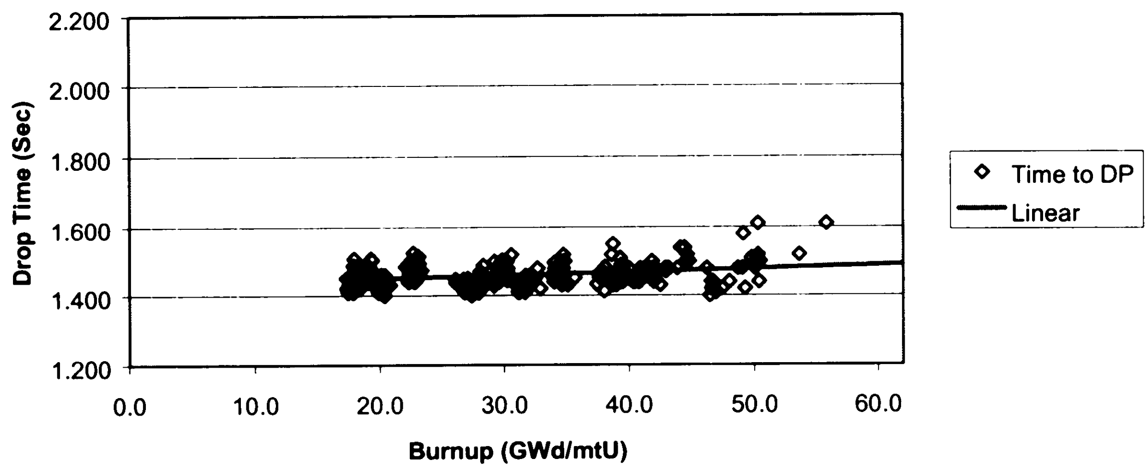


Figure 4.6-4
Time to Dashpot - McGuire 2



The figures exhibit no appreciable corrrelation of drop time verses burnup as is shown by the near zero slope of the linear fits. This fact coupled with over 0.45 seconds of margin relative to the technical specification limit justifies an extrapolation to 62,000 MWd/mtU burnup. Furthermore, no Mark-BW fuel assembly has experienced an incomplete rod insertion.

4.7 Defects

The fuel reliability for the Mark-BW fuel design is excellent with over 2400 fuel assemblies delivered by year-end 2000. At the end of 2000, all plants using the Mark-BW design were operating defect free. Figure 4.7-1 below shows the failure history for the Mark-BW product since it was introduced in 1991.

Figure 4.7-1
Framatome ANP Failure Rate for Mk-BW Fuel

[ ]

In the ten years the Mark-BW has been utilized there have been eight fuel rod failures identified. Four are known to be caused by debris, two failures are attributable to fuel manufacturing, and two failures have not been determined. These eight failures can be broken down into five first cycle and three third cycle failures. Mark-BW has proven to be a reliable, problem-free design with an overall failure rate of [ ]. Changes to the manufacturing process have eliminated the third cycle failure mechanisms in future fuel for two of the three failures. Based on the burnup of the failed rods and the time of failure there is no indication that the failures are related to burnup. Increasing the burnup limit from 60,000 to 62,000 MWd/mtU will have no adverse affect on fuel reliability.

5.0 Examinations

There are currently two applicable topical reports that have Safety Evaluation Report (SER) requirements to collect additional PIE data as a condition of approval. These are the Extended Burnup Topical Report Reference 1 (BAW-10186) and the M5™ Applications Topical Report Reference 2 (BAW-10227). In summary, the requirements of these topicals are to obtain additional PIE data at burnups that exceed those presented in the report up to the current licensed limit. In some cases, the data is to be collected from LTA programs and in others the data will come from batch production assemblies. Table 5.0-1 below summarizes the specific commitments contained in these two topical reports.

Table 5.0-1
Inspection Plans

PIE Data	BAW-10186 Extended BU	BAW-10227 M5™ Applications
FA Visual	LTA	LTA
Fuel Rod Oxide	LTA	LTA + Batch
GT Oxide		LTA
Rod Diameter	LTA	LTA + Batch
Rod Growth		LTA + Batch
FA Growth		LTA + Batch
Shoulder Gap		LTA + Batch
Rod Bow	LTA	LTA + Batch
FA Bow	LTA	LTA
CRA Drop Time	LTA	
CRA Drag	LTA	
Rod Wear		LTA
HDS Height	LTA	
Hot Cell Work		LTA

6.0 Conclusion

The original Framatome ANP extended burnup topical report (BAW-10186P-A) was approved by the NRC in 1997. The NRC safety evaluation report for that document approved the Mark-BW fuel assembly design for a rod average burnup limit of 60,000 MWd/mtU. Since that approval, Framatome ANP has acquired additional higher burnup data for both the Mark-B and Mark-BW fuel designs. Framatome ANP has demonstrated the similarity of the two designs. Therefore, the additional data for the Mark-B fuel is directly applicable to the Mark-BW fuel.

The data presented in this supplement address the phenomena of fuel corrosion and growth. All the data support a burnup limit of 62,000 MWd/mtU for the Mark-BW fuel design. The other fuel damage criteria specified in Standard Review Plan 4.2 were addressed in the original submittal of BAW-10186 and provide acceptable performance up to a rod average burnup of 65,000 MWd/mtU. All analyses in BAW-10186P-A were performed with NRC approved methodology.

Framatome ANP is committed to performing additional post irradiation examinations of high burnup fuel. Data will be acquired on LTAs and full batches of fuel. In addition to oxide and growth measurements, control rod drop times will be measured to ensure continued acceptable performance. The results of these examinations will be presented to the NRC during fuel vendor fuel performance review meetings.

Based on the similarity of the Framatome ANP fuel designs, the additional data acquired since the review of BAW-10186P-A, satisfactory performance against the SRP criteria, and the commitment to acquire additional data, it is concluded that the Mark-BW fuel assembly will provide acceptable performance up to rod average burnup of 62,000 MWd/mtU.

7.0 References

1. BAW-10186P-A Revision 1, Extended Burnup Evaluation, April 2000.

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

3. U.S. Nuclear Regulatory Commission. July 1981. "Section 4.2, Fuel System Design." In Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants--LWR Edition. NUREG-0800, Revision 2, U.S. Nuclear Regulatory Commission, Washington, D.C.