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Dominion®

March 23, 2009

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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Serial No.:	09-084A
NLOS/WDC	R0
Docket No.:	50-423
License No.:	NPF-49

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING A SPENT FUEL POOL CRITICALITY LICENSE AMENDMENT REQUEST

Dominion Nuclear Connecticut, Inc. (DNC) submitted a stretch power uprate (SPU) license amendment request (LAR) for Millstone Power Station Unit 3 (MPS3) in letters dated July 13, 2007 (Serial Nos. 07-0450 and 07-0450A). The SPU LAR included a revised spent fuel pool (SFP) criticality analysis with proposed changes in technical specification (TS) requirements. DNC separated the MPS3 SFP TS change request from the MPS3 SPU request via letter dated March 5, 2008 (Serial No. 07-0450D).

In a letter dated August 8, 2008, the Nuclear Regulatory Commission (NRC) transmitted a request for additional information (RAI) regarding the SFP TS. DNC responded to RAI questions 1 through 19 in a letter dated September 30, 2008 (Serial No. 08-0511A). Subsequently, in a letter dated February 2, 2009, the NRC requested additional information. DNC responded to RAI questions 20, 22, 23, and 25 in a letter dated March 5, 2009 (Serial No. 09-084).

In a February 25, 2009 telecon between Mr. W. Bartron of DNC and Mr. H. Chernoff of the NRC, it was agreed the responses to RAI questions 21 and 24 would be submitted by March 24, 2009. The responses to RAI questions 21 and 24 are provided in the attachments to this letter.

Attachment 1 contains the responses to RAI questions 21 and 24. The information in Figure 1 and Figure 2 in the response to RAI question 24 is used to update the information provided in DNC letter dated July 13, 2007 (ADAMS No. ML072000386), Attachment 3, "Mark-up of The Operating License and Technical Specifications Pages," Figure 3.9-3 and Figure 3.9-5. The updated Figure 3.9-3 and Figure 3.9-5 are provided in Attachment 2.

The information provided by this letter does not affect the conclusions of the significant hazards consideration discussion in the December 13, 2007 DNC letter (Serial No. 07-0450C).

Should you have any questions in regard to this submittal, please contact Mrs. Wanda Craft at 804-273-4687.

Sincerely,

J. Alan Price
Vice President – Nuclear Engineering

Commitments made in this letter:
1. None.

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by J. Alan Price, who is Vice President - Nuclear Engineering of Dominion Nuclear Connecticut, Inc. He has affirmed before me that he is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 23 day of March, 2009.

My Commission Expires: ____________________.

Diane M Phillipo
Notary Public

DIANE M PHILLIPO
NOTARY PUBLIC
MY COMMISION EXPIRES 12/31/2010

Attachment:

1. Attachment 1: Response to Request for Additional Information (RAI) Questions 21 and 24 Regarding the Spent Fuel Pool Criticality License Amendment Request
2. Attachment 2: Response to Request for Additional Information (RAI) Questions 21 and 24 Regarding the Spent Fuel Pool Criticality License Amendment Request, Updated Figure 3.9-3 and Figure 3.9-5

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ATTACHMENT 1

RESPONSE TO RAI QUESTIONS 21 and 24

REGARDING THE SPENT FUEL POOL CRITICALITY LICENSE AMENDMENT REQUEST

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

RESPONSE TO RAI QUESTIONS 21 AND 24 REGARDING THE SPENT FUEL POOL CRITICALITY LICENSE AMENDMENT REQUEST

Question 21

In the response to RAI 1 - 3 regarding the axial burnup distribution modeling, it is stated that Profile 5 from NUREG/CR 6801, "Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses," March 2003, was used. In NUREG/CR-6801, Figures 3 and 7 - 18 show various profile shapes at various burnup intervals. Additionally, Figures 19 - 30 statistically demonstrate the bounding profile for various burnup intervals. Demonstrate Profile 5 is bounding for all MPS3 fuel axial burnup profiles, in particular the 15-25 gigawatt day per metric ton uranium (GWd/MTU) range.

Response:

The response to this question will address whether the WCAP-16721 use of Profile 5 in the 15-25 GWd/MTU burnup range is bounding for all MPS3 fuel axial burnup profiles. Additionally, the burnup range for investigation in this RAI response was increased to 15-60 GWd/MTU to further ensure the proposed Technical Specification curves are bounded by Millstone Power Station Unit 3 (MPS3) axial fuel profiles.

Background

The WCAP-16721 method was to use the more limiting of either a uniform axial burnup profile, or an axial burnup shape from NUREG Profile 5, over the entire burnup range covered by the proposed Technical Specification curves. WCAP-16721 used a 4 zone axial model for calculation of fuel assembly reactivity in the spent fuel pool (SFP). The 4 zone axial model used three 6 inch nodes at the top of the fuel and one large 4^{th} node to cover the rest of the fuel.

RAI 24 questioned the acceptability of using the 4 zone model, and in particular the use of the top 2 nodes of the 4 zone model to appropriately screen the MPS3 axial shapes to arrive at a limiting axial shape for comparison to the two shapes used in the WCAP. As discussed in the response to RAI 24, Dominion concurred the screening of MPS3 shapes using the top 2 nodes from the 4 zone model was not always conservative relative to use of a screening based on the top 1/3 of the 24 node assembly burnup profile (Top-1/3 Assembly screening method).

Fundamental to the response to this question is the correct identification of MPS3 limiting axial shapes. Therefore, all screening of MPS3 axial shapes in this RAI response is performed with the Top-1/3 screening method using 24 axial node MPS3 axial shapes.

Once limiting MPS3 axial shapes are identified, the reactivity calculations are carried out in 24 axial nodes, to fully capture both the top and bottom axial shapes effect on SFP reactivity.

Screening of MPS3 Axial Shapes

The MPS3 profiles with the lowest relative burnup in the top 1/3 of the assembly were used for the limiting profile cases. The Top-1/3 Assembly method was shown in RAI 24 to select profiles with equivalent or slightly higher reactivity than those selected using only the top two nodes. The MPS3 library of axial shapes used is a large multi-cycle library of MPS3 axial burnup profiles accumulated over the operating history of the plant, since Cycle 1. Due to the importance of blankets at the end of the fuel, the results of the screening are provided separately for 3 types of fuel; (1) fuel with no axial blankets (No Blanket fuel), (2) fuel with natural enriched blankets, and (3) fuel with mid-enriched blankets (nominal 2.6 w/o U235). Table 21-2a shows a summary of the limiting axial shapes selected using the Top 1/3 Assembly method. Table 21-2b shows the detailed 24 node limiting burnup shapes.

Spent Fuel Pool Reactivity Calculations

The response to this question will provide SFP reactivity differences between:

(1) Limiting MPS3 axial burnup profiles identified using the Top 1/3 Assembly method modeled with a 24 axial zone model for reactivity calculations, hereafter referred to as "MPS3 limiting profile", versus
(2) The WCAP-16721 Limiting Axial Profile, hereafter referred to as the "WCAP limiting profile". The burnup credit curves in WCAP-16721 (Figures 5-2 through 5-4) are constructed using the more limiting of two calculations – one using a uniform burnup profile and one based on a 4 axial zone representation of Profile 5 from NUREG/CR-6801 (shown in Figure 2-1 of WCAP-16721).

If the k_{eff} of the "MPS3 limiting profile" 24 zone profile is lower than the k_{eff} of the corresponding "WCAP limiting profile", then the burnup credit curve in WCAP-16721 and the use of Profile 5 therein is bounding for MPS3 profiles. Conversely, if the k_{eff} of the "MPS3 limiting profile" 24 zone profile is higher than the k_{eff} of the corresponding "WCAP limiting profile", then the burnup credit curve in WCAP-16721 would need to be modified.

SFP rack k_{eff} cases were run using the WCAP Region II and Region III SFP rack models. For the MPS3 limiting profiles, 24 equally spaced zones were used to represent the burnup profile using PARAGON and SCALE5.1. Use of those codes for comparison cases is addressed in RAI 23. A 24 axial zone model was used for the MPS3 limiting profiles to avoid additional concerns about the adequacy of the 4 zone representation expressed in other RAI questions. Depletion calculations for each profile were performed at the same conditions described for the 4 zone model in the WCAP, except the zone burnup and moderator temperatures were chosen based on the 24 zone burnup distributions. For the WCAP limiting profile cases, uniform profile and 4 zone Profile 5 cases were re-run with PARAGON and SCALE5.1 in order to maintain a consistent basis for comparison.

Results

Due to the importance of blankets at the end of the fuel, reactivity results are provided separately for 3 types of fuel; (1) fuel with natural enriched blankets, and (2) fuel with mid-enriched blankets (nominal 2.6 w/o U235), (3) fuel with no axial blankets.

Natural Blanket Fuel Results

Table 21- 3 provides the results of the reactivity calculations for natural enrichment blankets. Results are provided for 3 w/o, 4 w/o and 5 w/o U235 fuel enrichments. Results are presented for various fuel burnups in Regions II and III. A positive value of Δk_{eff} means the WCAP limiting profile is conservative. A negative value means the WCAP limiting profile is non-conservative, and action is required to resolve the non-conservatism.

The choice of fuel burnups selected for Regions II and III calculations are important. The fuel burnups chosen for calculation in Table 21-3 straddle the required burnup vs enrichment curves that have been proposed. Table 21-1 shows the WCAP-16721 Burnup Credit Values 3 w/o, 4 w/o and 5 w/o U235 fuel, for both Regions II and III with 0 fuel decay time. For example, Region II at 4 w/o U235 was evaluated at 25000 and 30000 megawatt day per metric ton (MWd/MTU). A 4 w/o U235 initial enrichment fuel assembly with a burnup less than 25000 MWd/MTU would not be allowed to be stored in Region II. A 4 w/o U235 initial enrichment fuel assembly with a burnup greater than 30000 MWd/MTU could be stored in Region II, but substantially higher average fuel burnups than the minimum required burnup mean lower overall SFP reactivity, which is a much larger effect than the "end effect" of concern. Thus, the selection of fuel burnups which straddle the Region II and III required fuel burnup curves are the appropriate fuel burnups for consideration.

As shown in Table 21-3, for natural enrichment blanket fuel, conservatism exists in the burnup credit curves except for 3 w/o fuel in Region III. For 3 w/o fuel in Region III, action, which is addressed later in this response, is required to resolve this non-conservatism.

Mid-Enriched Blanket Fuel Results

Table 21-4 provides the results of the reactivity calculations for mid-enriched Blankets. Results are provided for 3 w/o, 4 w/o and 5 w/o U235 fuel enrichments. Results are presented for various fuel burnups in Regions II and III. A positive value of Δk_{eff} means the WCAP limiting profile is conservative. A negative value means the WCAP limiting profile is non-conservative, and action is required to resolve the non-conservatism.

The choice of fuel burnups selected for Regions II and III calculations are important. The fuel burnups chosen for calculation in Table 21-4 straddle the required burnup vs enrichment curves that have been proposed. The logic of this was discussed earlier for natural blankets, and this logic is the same for mid-enriched Blankets.

For mid-enriched blanket fuel conservatism is identified at 5 w/o in Region II and at 4 w/o and 5 w/o in Region III. There are two slightly non-conservative points for mid-enriched blanket fuel in Region II (3 w/o and 4 w/o) and one in Region III (3 w/o). For 3 w/o fuel in Regions II and III, action is required to resolve this non-conservatism. For 4 w/o fuel in Region II, action, which is addressed later in this response, is required to resolve this non-conservatism.

Also shown in Table 21-4 are results for a Region III case with 25 years decay time. This case is provided to determine whether the reactivity non-conservatism increases or decreases with increasing decay time. For 3 w/o U235 fuel at 30 GWd/MTU, the 25 year decay time non-conservatism is less than the no decay time non-conservatism. Therefore, action taken to resolve the no decay time result will be sufficient for longer decay times as well. Any burnup penalty applied to the 0 decay time case will also be applied to the decay time cases.

No Blanket Fuel Results

<u>Future Use of No Blanket Fuel</u>

In order to limit the scope of this response, Dominion will not use No Blanket fuel in MPS3 in the future. This means this response applies only to existing No Blanket fuel.

To implement this restriction of no future use of No Blanket fuel at MPS3, a footnote will be added to proposed Technical Specification Figure 3.9-3 for Region II fuel storage, and Figure 3-9-5 for Region III for storage of Post-Uprate fuel. Figures 1 and 2 show this footnote.

The footnote reads: "For assemblies from Post-Uprate (3650 MWt) Cores, the nominal fuel enrichment of blankets must be $\leq$ 2.6 w/o U-235, and nominal blanket length must be at least 6 inches on both ends of the fuel. " The restrictions contained in this footnote ensure fuel is within the analyzed conditions of the analysis in this RAI response.

<u>Existing No Blanket Fuel</u>

Given the above, the calculations to be presented in this RAI response address No Blanket fuel which currently exists in the SFP. Only a few batches of No Blanket fuel have been used at MPS3, and these date back to the first few cycles of MPS3 operation.

Fuel Storage Region I does not need to be evaluated because the maximum fuel burnup credited is less than 6000 MWd/MTU, and therefore axial end effects do not need to be considered for such a low burnup.

Fuel Storage Region II must be evaluated for the existing No Blanket fuel since proposed TS Figure 3.9-3 applies to all fuel stored in Region II, that is, cores operated at both the 3411 MWt (Pre-Uprate) and 3650 MWt (Post-Uprate) power levels.

Fuel Storage Region III does not need to be evaluated for existing No Blanket fuel since:

- Proposed TS Figure 3.9-5 applies to storage of fuel in Region III, from post uprate (3650 MWt) cores. Since there will be no fuel with no blankets per the footnote in this proposed TS Figure, no further analysis is needed.
- Existing TS Figure 3.9-4 applies to storage of fuel in Region III, from Pre-Uprate (3411 MWt) cores. This Figure 3.9-4 is not altered, nor is it related to the WCAP-16721 analysis provided in this Technical Specification change, and the only change to this Figure is to change the title of the Figure to reflect it is valid only for assemblies from Pre-Uprate (3411 MWt) Cores. MPS3 No Blanket fuel currently in the SFP, from Pre-Uprate (3411 MWt) cores continue to be able to be stored in Region III per this existing TS Figure. This figure was previously approved by the NRC, and was retained in the Technical Specifications to allow fuel from Pre-Uprate (3411 MWt) cores to be stored in Region III, provided it meets the requirements of the TS Figure.

Therefore, analysis of Region II is required to support this RAI response for the existing No Blanket fuel.

Table 21- 5 provides the results of the reactivity calculations for existing No Blanket fuel in Region II. Results are provided for 2.9 w/o and 3.8 w/o U235 fuel enrichments. A positive value of Δk_{eff} means the WCAP limiting profile is conservative. A negative value means the WCAP limiting profile is non-conservative, and action is required to resolve the non-conservatism.

The limiting Top-1/3 Assembly axial profile for all No Blanket fuel is for a 2.9 w/o assembly discharged from Cycle 1 with 22,160 MWd/MTU. This profile is used for the 2.9 w/o reactivity comparison. The limiting Top-1/3 Assembly profile for 3.8 w/o fuel is an assembly with 32,914 MWd/MTU discharge burnup. This profile is used for the 3.8 w/o reactivity comparison. Both comparisons are performed using the actual assembly burnup, which is larger than the WCAP burnup requirement. Use of higher than required burnup is conservative because the end effect increases with increasing burnup.

Analyzing enrichments greater than 3.8 w/o U235 is not necessary, since the enrichment of 3.8 w/o U-235 is the highest enrichment of the existing No Blanket fuel. There is some No Blanket fuel lower than 2.9 w/o U235, however, for very low enrichments, the required fuel burnup to allow storage is so low as to not be of concern for end effect reactivity. Since the limiting Top-1/3 Assembly comparison covers only existing No Blanket fuel from completed MPS3 cycles, credit has been taken for as-built fuel density, dish and chamfer fractions, Pre-Uprate (3411 MWt) core power, and as-operated cycle soluble boron concentration.

The results in Table 21-5 show for No Blanket fuel, both cases are slightly non-conservative. However, the degree of non-conservatism is bounded by the mid-enriched blanket results at 3 w/o and 4 w/o enrichment, so no additional action is required to resolve this non-conservatism. The actions taken to resolve the mid-enriched blanket fuel non-conservatism in Region II will also resolve the Region II non-conservatism for No Blanket fuel.

Modifications to Proposed Region II and III Burnup Curves

Based on the results provided, non-conservatisms have been identified in the originally submitted WCAP curves for Region II and Region III minimum fuel burnup at various points on the curve. The proposed Region II and III burnup curves will be modified to offset the above identified non-conservatism.

Table 21-6 summarizes the non-conservative reactivity values (Δk_{eff} plus two RSS 1- σ) and provides a calculation of equivalent additional burnup credit required to offset the excess reactivity identified. The most limiting of the natural and mid-enriched blanket cases at 0 decay time are shown. The sensitivity relationship between burnup and Δk_{eff} in Table 21-6 was determined using 24 zone limiting Millstone profile k_{eff} data used to construct Tables 21-3 and 21-4.

Based on the results in Table 21-6, the Region II required fuel burnups at 3 w/o and 4 w/o U235 at all decay times are increased by 0.5 GWd/MTU. Based on the results in Table 21-6, the Region III required fuel burnups at 3 w/o U235 at all decay times are increased by 1.5 GWd/MTU.

The proposed revised tabular values for the Region II and Region III burnup/enrichment limits are provided in Table 21-7 (Region II) and Table 21-8 (Region III). These are plotted in Figures 1 (Region II) and 2 (Region III).

Table 21-1

WCAP-16721 Burnup Credit Values for 3, 4, and 5 w/o U_{235} Fuel With 0 Decay Time

SFP Region	Initial Fuel Enrichment (w/o U_{235})	Burnup Required (MWd/MTU)
2	3	16891
2	4	29161
2	5	42338
3	3	25516
3	4	40789
3	5	55566

Table 21-2a
Limiting Millstone Shapes Selected Using Top-1/3 Method

Region	Blanket Type	Burnup Curve Enrichment (w/o U235)	Burnup Range Searched (GWd/MTU)	Enrichment Range Searched (w/o U235)	Limiting Profile Enrich. (w/o U235)	Limiting Profile Burnup (GWd/MTU)	Limiting Profile Cycle
2	NONE	2.9	All Discharge Fuel	ALL	2.9	22.2	1
2	NONE	3.8	All Discharge Fuel	3.8	3.8	32.9	4
2	Natural	3	All End of Cycle Fuel	≤ 4.5	4.4	23.6	5
2	Natural	4	All End of Cycle Fuel	≤ 4.5	4.4	23.6	5
2	Natural	5	All End of Cycle Fuel	> 4.5	4.6	13.2	6
2	2.6 w/o	3	All End of Cycle Fuel	≤ 4.5	4.1	27.2	13
2	2.6 w/o	4	All End of Cycle Fuel	≤ 4.5	4.1	27.2	13
2	2.6 w/o	5	All End of Cycle Fuel	> 4.5	4.9	27.6	13
3	Natural	3	All End of Cycle Fuel	≤ 4.5	4.4	23.6	5
3	Natural	4	All End of Cycle Fuel >30	≤ 4.5	4.4	34.9	6
3	Natural	5	All End of Cycle Fuel >50	> 4.5	4.6	50.4	7
3	2.6 w/o	3	All End of Cycle Fuel	≤ 4.5	4.1	27.2	13
3	2.6 w/o	4	All End of Cycle Fuel >30	≤ 4.5	4.4	50.0	9
3	2.6 w/o	5	All End of Cycle Fuel >50	> 4.5	4.95	55.1	12

Table 21-2b

Limiting Millstone Shapes Selected Using Top-1/3 Method

	Natural Blankets					Mid-enriched Blankets				No Blankets	
Mesh	Mid-Point (cm)	Cycle 5	Cycle 6	Cycle 6	Cycle 7	Cycle 13	Cycle 9	Cycle 13	Cycle 12	Cycle 1	Cycle 4
24	358.69	0.182	0.224	0.189	0.243	0.446	0.441	0.406	0.393	0.410	0.453
23	343.42	0.628	0.670	0.653	0.707	0.717	0.733	0.709	0.728	0.647	0.721
22	328.16	0.827	0.870	0.842	0.892	0.859	0.886	0.850	0.897	0.826	0.909
21	312.90	0.949	0.981	0.962	0.993	0.948	0.970	0.942	0.982	0.938	1.004
20	297.63	1.014	1.036	1.027	1.043	0.997	1.014	0.993	1.024	1.007	1.049
19	282.37	1.048	1.065	1.061	1.067	1.024	1.037	1.021	1.047	1.048	1.071
18	267.11	1.067	1.080	1.080	1.079	1.040	1.050	1.039	1.059	1.073	1.082
17	251.84	1.079	1.088	1.091	1.087	1.051	1.059	1.051	1.067	1.088	1.088
16	236.58	1.089	1.095	1.100	1.092	1.060	1.065	1.061	1.073	1.098	1.092
15	221.32	1.101	1.101	1.106	1.097	1.068	1.071	1.070	1.078	1.106	1.096
14	206.05	1.115	1.109	1.113	1.101	1.075	1.077	1.079	1.083	1.113	1.099
13	190.79	1.127	1.115	1.119	1.105	1.083	1.083	1.087	1.087	1.120	1.102
12	175.53	1.137	1.121	1.127	1.110	1.091	1.088	1.096	1.092	1.127	1.105
11	160.26	1.146	1.126	1.134	1.115	1.099	1.094	1.105	1.097	1.135	1.109
10	145.00	1.156	1.133	1.142	1.120	1.107	1.100	1.114	1.102	1.143	1.112
9	129.74	1.165	1.139	1.151	1.125	1.115	1.106	1.123	1.107	1.151	1.116
8	114.47	1.175	1.145	1.159	1.131	1.123	1.111	1.132	1.112	1.158	1.119
7	99.21	1.182	1.150	1.165	1.135	1.130	1.116	1.139	1.115	1.162	1.121
6	83.95	1.183	1.150	1.166	1.135	1.133	1.117	1.143	1.116	1.158	1.119
5	68.68	1.170	1.139	1.153	1.126	1.127	1.109	1.136	1.107	1.138	1.107
4	53.42	1.122	1.100	1.109	1.093	1.097	1.082	1.105	1.079	1.089	1.072
3	38.16	1.003	0.999	0.998	1.003	1.017	1.010	1.023	1.005	0.986	0.984
2	22.89	0.769	0.779	0.782	0.802	0.856	0.847	0.859	0.831	0.791	0.788
1	7.63	0.209	0.247	0.216	0.264	0.501	0.496	0.464	0.460	0.489	0.481
	Cycle	Cycle 5	Cycle 6	Cycle 6	Cycle 7	Cycle 13	Cycle 9	Cycle 13	Cycle 12	Cycle 1	Cycle 4
	Burnup (MWd/MTU)	23567	34854	13206	50371	27194	50008	27578	55058	22160	32914
	Enrichment (w/o U235)	4.4	4.4	4.6	4.6	4.1	4.4	4.9	4.95	2.9	3.8

Table 21-3

Reactivity Difference Between WCAP-16721 k_{eff} (WCAP limiting profile) and Limiting Millstone Profile 24 Zone (MPS3 limiting profile) k_{eff} For Fuel Assemblies with Natural Enrichment Blankets

Burnup (MWd/MTU)	Region II		Region III	
	Δk_{eff} (WCAP limiting profile – MPS3 limiting profile)	RSS 1-σ	Δk_{eff} (WCAP limiting profile – MPS3 limiting profile)	RSS 1-σ
3 w/o U235 Enrichment				
15,000	0.00602	0.00044		
20,000	0.00250	0.00045		
25,000			**-0.00221**	0.00045
30,000			**-0.00087**	0.00044
4 w/o U235 Enrichment				
25,000	0.00338	0.00045		
30,000	0.00137	0.00046		
35,000				
40,000			0.01075	0.00042
45,000			0.01305	0.00044
5 w/o U235 Enrichment				
40,000	0.00933	0.00048		
45,000	0.00991	0.00047		
50,000				
55,000			0.02416	0.00044
60,000			0.02736	0.00042

Note 1 - The limiting Millstone profile calculations are performed with 24 axial nodes

Note 2 – A negative value of Δk_{eff} means the limiting MPS3 limiting profile is more reactive than the WCAP limiting profile used to derive the burnup credit curves, therefore a negative value results in WCAP-16721 proposed burnup credit curve being non-conservative.

Table 21-4

Reactivity Difference Between WCAP-16721 k_{eff} (WCAP limiting profile) and Limiting Millstone Profile 24 Zone (MPS3 limiting profile) k_{eff} For Fuel Assemblies with Mid-Enriched Blankets

Burnup (MWd/MTU)	Region II		Region III	
	Δk_{eff} (WCAP limiting profile – MPS3 limiting profile)	RSS 1-σ	Δk_{eff} (WCAP limiting profile – MPS3 limiting profile)	RSS 1-σ
3 w/o U235 Enrichment				
15,000	0.00051	0.00045		
20,000	**-0.00238**	0.00045		
25,000			**-0.00714**	0.00044
30,000			**-0.00705**	0.00043
30,000 (25 year decay time)			**-0.00458**	0.00040
4 w/o U235 Enrichment				
25,000	0.00005	0.00045		
30,000	**-0.00147**	0.00045		
35,000				
40,000			0.00546	0.00043
45,000			0.00783	0.00045
5 w/o U235 Enrichment				
35,000				
40,000	0.00285	0.00049		
45,000	0.00412	0.00046		
50,000				
55,000			0.01647	0.00041
60,000			0.01916	0.00043

Note 1 - The limiting Millstone profile calculations are performed with 24 axial nodes

Note 2 – A negative value of Δk_{eff} means the limiting MPS3 limiting profile is more reactive than the WCAP limiting profile used to derive the burnup credit curves, therefore a negative value results in WCAP-16721 proposed burnup credit curve being non-conservative

Table 21-7
Minimum Required Assembly-Average Burnup versus Initial ^{235}U Enrichment and Decay Time for the "Region II" Storage Configuration

Initial Enrichment (w/o ^{235}U)	Assembly Average Burnup (MWd/MTU)		
	0 yr Decay	5 yr Decay	10 yr Decay
1.81	0	0	0
3	17391	16307	15578
4	29661	27699	26658
5	42338	39652	37990

The required assembly burnup as a function of ^{235}U enrichment in the "Region III" storage configuration is described by the following polynomials:

Assembly Burnup (0 yr decay) = $+399.357\ e^3\ -4588.789\ e^2\ +29615.297\ e\ -40938.444$

Assembly Burnup (5 yr decay) = $+418.782\ e^3\ -4744.890\ e^2\ +29111.276\ e\ -39629.950$

Assembly Burnup (10 yr decay) = $+327.320\ e^3\ -3801.851\ e^2\ +25582.080\ e\ -35789.252$

Table 21-8
Minimum Required Assembly-Average Burnup versus Initial ^{235}U Enrichment and Decay Time for the "Region III" Storage Configuration for Post Uprate Cores

Initial Enrichment (w/o ^{235}U)	Assembly Average Burnup (MWd/MTU)				
	0 yr Decay	5 yr Decay	10 yr Decay	15 yr Decay	20 yr Decay
1.45	0	0	0	0	0
3	27,016	25,104	23,972	23,213	22,530
4	40,789	38,017	36,085	34,840	33,893
5	55,566	52,057	49,717	47,978	46,835

The required assembly burnup as a function of ^{235}U enrichment in the "Region III" storage configuration is described by the following polynomials:

Assembly Burnup (0 yr decay) = $+545.349\ e^3\ -6042.196\ e^2\ +35890.432\ e\ -40999.978$

Assembly Burnup (5 yr decay) = $+521.408\ e^3\ -5693.407\ e^2\ +33474.718\ e\ -38157.534$

Assembly Burnup (10 yr decay) = $+584.317\ e^3\ -6252.307\ e^2\ +34259.408\ e\ -38312.032$

Assembly Burnup (15 yr decay) = $+582.784\ e^3\ -6237.911\ e^2\ +33729.357\ e\ -37569.053$

Assembly Burnup (20 yr decay) = $+572.848\ e^3\ -6084.680\ e^2\ +32760.368\ e\ -36455.896$

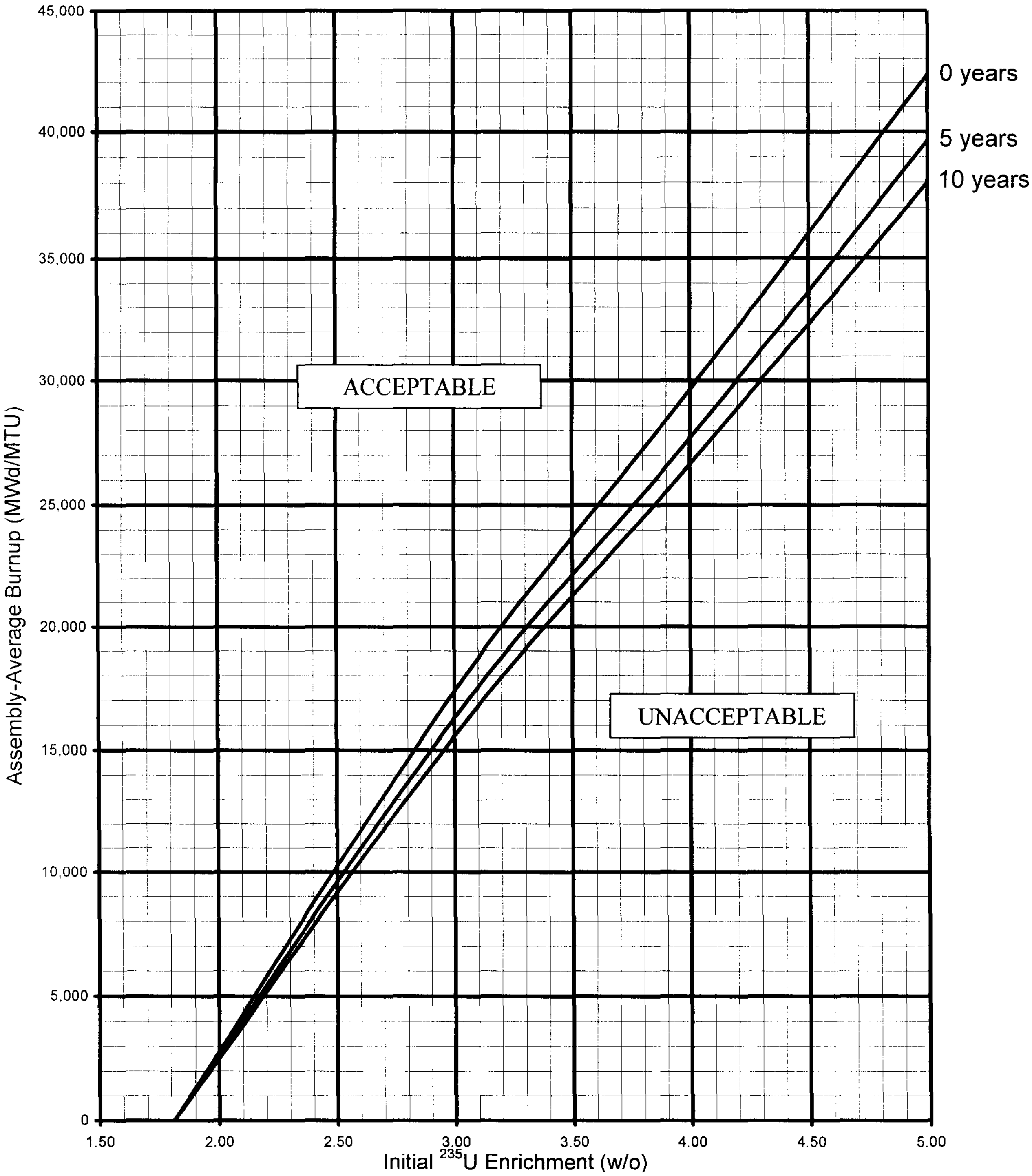


Figure 1: Minimum Fuel Assembly Burnup and Decay Time Versus Nominal Initial Enrichment for Region 2 Storage Configuration

NOTE: For assemblies from Post-Uprate (3650 MWt) Cores, the nominal fuel enrichment of blankets must be ≤ 2.6 w/o U-235, and nominal blanket length must be at least 6 inches on both ends of the fuel.

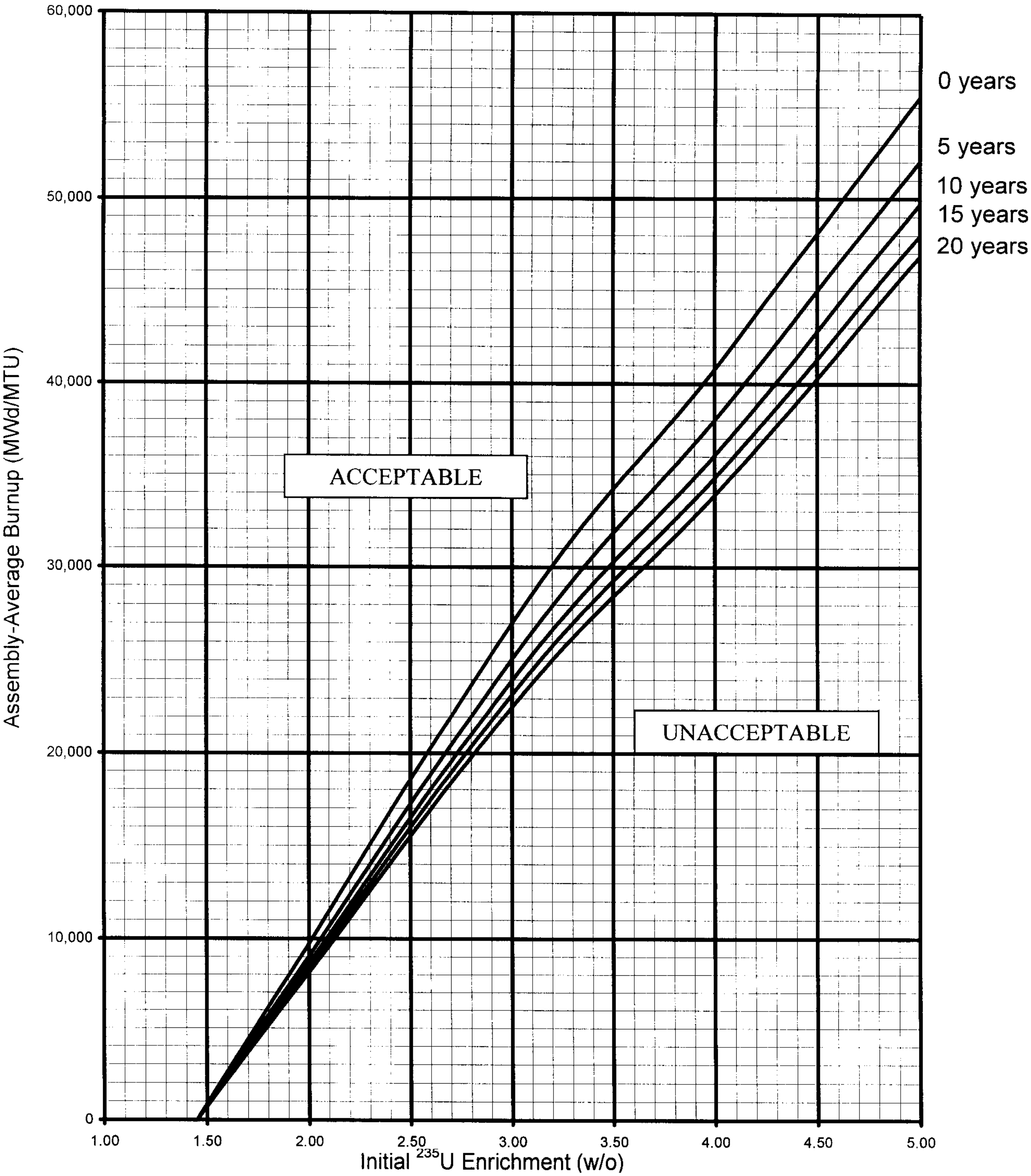


Figure 2: Minimum Fuel Assembly Burnup and Decay Time Versus Initial Enrichment for Region 3 Storage Configuration for Assemblies from Post Uprate (3650 MWt) Cores

NOTE: For assemblies from Post-Uprate (3650 MWt) Cores, the nominal fuel enrichment of blankets must be ≤ 2.6 w/o U-235, and nominal blanket length must be at least 6 inches on both ends of the fuel.

Question 24

In the response to RAI 3, it is stated that the limiting axial burnup profile is chosen based on the relative burnup of the top two nodes. A comparison of the relative burnup in the top two nodes is not how the limiting profile was determined in NUREG/CR-6801, therefore the NRC staff is unsure how this method adequately determines the limiting profile. NUREG/CR-6801 Appendix A, Axial Discretization and Boundary Conditions, indicates that more than the top two nodes are important for determining the 'end effect.' NUREG/CR-6801 Appendix A indicates that the 'end effect' must consider the top third of the assembly. Additionally, NUREG/CR-6801 states, "... that often a very small secondary peak is observed at the other end of the fuel rod, due to the reduced burnup at that end as well." Provide additional justification to support your method or demonstrate, with justification, the limiting profile.

Response:

Essentially, two questions are asked: (1) Why is the Top-2 node method of screening axial shapes acceptable when the NUREG indicates the top third of the assembly is important, and (2) How did MPS3 address the small secondary K-effective peak at the bottom of the fuel. Responses to each of these two questions are provided below.

Top-2 Node Screening vs Top-1/3 Assembly Screening of Axial Shapes

To address the concern that use of the top two nodes (Top-2 Node method) may not be sufficient for determination of limiting axial profiles, a library of measured MPS3 axial burnup shapes were screened using 2 different methods. First, the library of axial shapes were screened using the burnup in the top third of the assembly (Top-1/3 Assembly method) and then the library was screened again using the Top-2 Node method. The MPS3 library of axial shapes used is a large multi-cycle library of MPS3 axial burnup profiles accumulated over the operating history of the plant, since Cycle 1. Due to the importance of blankets at the end of the fuel, the results of the screening are provided separately for 3 types of fuel; (1) fuel with no axial blankets, (2) fuel with natural enriched blankets, and (3) fuel with mid-enriched blankets (nominal 2.6 w/o U235).

The results of this axial shape screening using the Top-2 Node method vs the Top-1/3 Assembly method were:

- For fuel assemblies with no axial blankets, the same limiting axial burnup profile was selected by both methods.
- For fuel assemblies with natural enrichment blankets, each method selected a different axial profile as limiting
- For fuel with enriched axial blankets each method selected a different axial profile as limiting.

Since the same limiting axial burnup profile was selected by each method for fuel with no blankets, the methods are equivalent for this type of fuel. Since different axial burnup profiles were selected by each method for fuel with natural blankets, and fuel with mid-enriched blankets, reactivity calculations are needed to assess the difference between the two methods.

In order to determine which method selected the highest reactivity profile, SFP rack k_{eff} cases were run at various fuel burnups from 10,000 to 30,000 MWd/MTU and at 3 w/o, 4 w/o and 5 w/o U235 fuel enrichments, using the WCAP Region II and Region III SFP rack models. Cases were run for both fuel with natural blankets, and fuel with mid-enriched blankets. The above cases were run with the limiting axial burnup shape from each of the two screening methods, to determine which gave the higher reactivity.

For this comparison, 24 equally spaced axial zones were used to represent the axial burnup profile using PARAGON and SCALE5.1. Use of those codes for comparison cases is addressed in RAI 23. Depletion calculations for each profile were performed at the same conditions described in WCAP-16721 for the 4 zone model, except the zone burnup and moderator temperatures were chosen based on the 24 zone axial burnup distributions. Uniform profile cases were also re-run with PARAGON and SCALE5.1 for reference, so that the total "end effect" reactivity can be considered, as well as the relative reactivity difference between the two methods.

The tables below, Table 24-1 for Natural Enriched Blankets, and Table 24-2 for Mid-Enriched Blankets, indicate the relative reactivity of each profile over the 10,000 to 30,000 MWd/MTU burnup range. Also included is the magnitude of the end effect, calculated as the difference between the Top-1/3 burnup profile k_{eff} and the uniform profile k_{eff}. These results indicate the more reactive profile is selected using the Top-1/3 Assembly selection method. Only six of the cases (end effect in bold print) in Table 24-1 and 12 of the cases in Table 24-2 have end effects greater than zero. For cases with negative end effects, the uniform profile is bounding for the determination of burnup credit curves.

Conclusion- Top-2 vs Top-1/3 Assembly Methods

Although the reactivity difference between the profiles is not large (less than 0.004 Δk_{eff}), and for much of the burnup range the uniform profile is the bounding case, the results do validate the concern in RAI 24. As a result of this finding, cases run for the response to RAI 21 rely on the Top-1/3 Assembly selection method rather than the Top-2 Node method.

Secondary Bottom K-effective Peaks

With regard to the small secondary fission rate peak at the bottom of the fuel, the lower moderator density at the top of the MPS3 fuel during depletion results in burnup profiles, which are slightly bottom skewed. MPS3 does not have axial power shaping rods. In

NUREG/CR-6801, limiting profiles that are not characteristic of axial power shaping rod effects are also bottom burnup skewed and have lower end node burnup at the top of the fuel than at the bottom of the fuel. MPS3 fuel also experiences greater plutonium generation in the top of the core due to the harder neutron spectrum. Both the overall axial burnup profile and the axial plutonium distribution will cause the end effect in the top of the fuel to be more important than the lower end effect. Further, since the axial burnup calculations provided in the response to RAI 21 are 24 axial node calculations using the Top-1/3 Assembly screening method, the secondary bottom axial peak will be directly included in the K-effective calculation.

Table 24-1

Reactivity Difference Between Top-2 Node Method Versus Top-1/3 Assembly Method of Screening Limiting Axial Burnup Profiles For Fuel Assemblies with Natural Enrichment Blankets

Burnup (MWd/MTU)	Region II			Region III		
	Δk_{eff} (Top 2 - top 1/3)	RSS 1-σ	End effect (Δk_{eff})	Δk_{eff} (Top 2 - top 1/3)	RSS 1-σ	End effect (Δk_{eff})
3 w/o						
10,000	-0.00132	0.00049	-0.00745	-0.00197	0.00045	-0.00706
15,000	-0.00095	0.00047	-0.00602	-0.00155	0.00043	-0.00532
20,000	-0.00228	0.00045	-0.00250	-0.00162	0.00042	-0.00269
25,000	-0.00196	0.00054	**0.00188**	-0.00292	0.00045	**0.00275**
30,000	-0.00108	0.00046	**0.00704**	-0.00171	0.00048	**0.00758**
4 w/o						
10,000	-0.00074	0.00048	-0.00781	-0.00145	0.00045	-0.00745
15,000	-0.00237	0.00047	-0.00744	-0.00126	0.00045	-0.00862
20,000	-0.00153	0.00046	-0.00617	-0.00246	0.00046	-0.00539
25,000	-0.00095	0.00047	-0.00338	-0.00247	0.00045	-0.00272
30,000	-0.00230	0.00051	**0.00178**	-0.00309	0.00042	**0.00153**
5 w/o						
10,000	-0.00114	0.00051	-0.00700	-0.00132	0.00045	-0.00768
15,000	-0.00179	0.00049	-0.00822	-0.00211	0.00047	-0.00836
20,000	-0.00170	0.00047	-0.00777	-0.00198	0.00047	-0.00775
25,000	-0.00161	0.00045	-0.00674	-0.00270	0.00045	-0.00633
30,000	-0.00232	0.00046	-0.00285	-0.00296	0.00046	-0.00326

Note 1 - The above calculations are performed with 24 axial nodes

Note 2 – A negative value of Δk_{eff} means the Top-1/3 Assembly method of screening shapes is conservative relative to the Top-2 Node Method

Note 3 – A negative end effect means the uniform profile has a higher k_{eff} than the Top-1/3 Assembly k_{eff}

Table 24-2

Reactivity Difference Between Top-2 Node Method Versus Top-1/3 Assembly Method of Screening Limiting Axial Burnup Profiles for Fuel Assemblies with Mid-Enriched Blankets

Burnup (MWd/MTU)	Region II			Region III		
	Δk_{eff} (Top 2 - top 1/3)	RSS 1-σ	End effect (Δk_{eff})	Δk_{eff} (Top 2 - top 1/3)	RSS 1-σ	End effect (Δk_{eff})
3 w/o						
10,000	-0.00200	0.00050	-0.00307	0.00012	0.00044	-0.00424
15,000	-0.00131	0.00045	-0.00061	-0.00162	0.00043	-0.00093
20,000	-0.00183	0.00045	**0.00427**	-0.00151	0.00043	**0.00363**
25,000	-0.00085	0.00045	**0.00991**	-0.00197	0.00050	**0.01028**
30,000	-0.00071	0.00043	**0.01578**	-0.00026	0.00043	**0.01567**
4 w/o						
10,000	-0.00075	0.00047	-0.00532	0.00015	0.00043	-0.00548
15,000	-0.00188	0.00048	-0.00366	-0.00189	0.00045	-0.00466
20,000	-0.00213	0.00046	-0.00152	-0.00302	0.00041	-0.00108
25,000	-0.00216	0.00047	**0.00137**	-0.00270	0.00048	**0.00201**
30,000	-0.00134	0.00045	**0.00588**	-0.00249	0.00047	**0.00553**
5 w/o						
10,000	-0.00097	0.00049	-0.00507	-0.00183	0.00043	-0.00501
15,000	-0.00130	0.00047	-0.00519	-0.00113	0.00045	-0.00576
20,000	-0.00241	0.00047	-0.00430	-0.00186	0.00045	-0.0046
25,000	-0.00184	0.00050	-0.00276	-0.00246	0.00046	-0.00256
30,000	-0.00228	0.00050	**0.00003**	-0.00202	0.00046	**0.00012**

Note 1 - The above calculations are performed with 24 axial nodes

Note 2 – A negative value of Δk_{eff} means the Top-1/3 Assembly method of screening shapes is conservative relative to the Top-2 Node Method

Note 3 – A negative end effect means the uniform profile has a higher k_{eff} than the Top-1/3 Assembly k_{eff}

ATTACHMENT 2

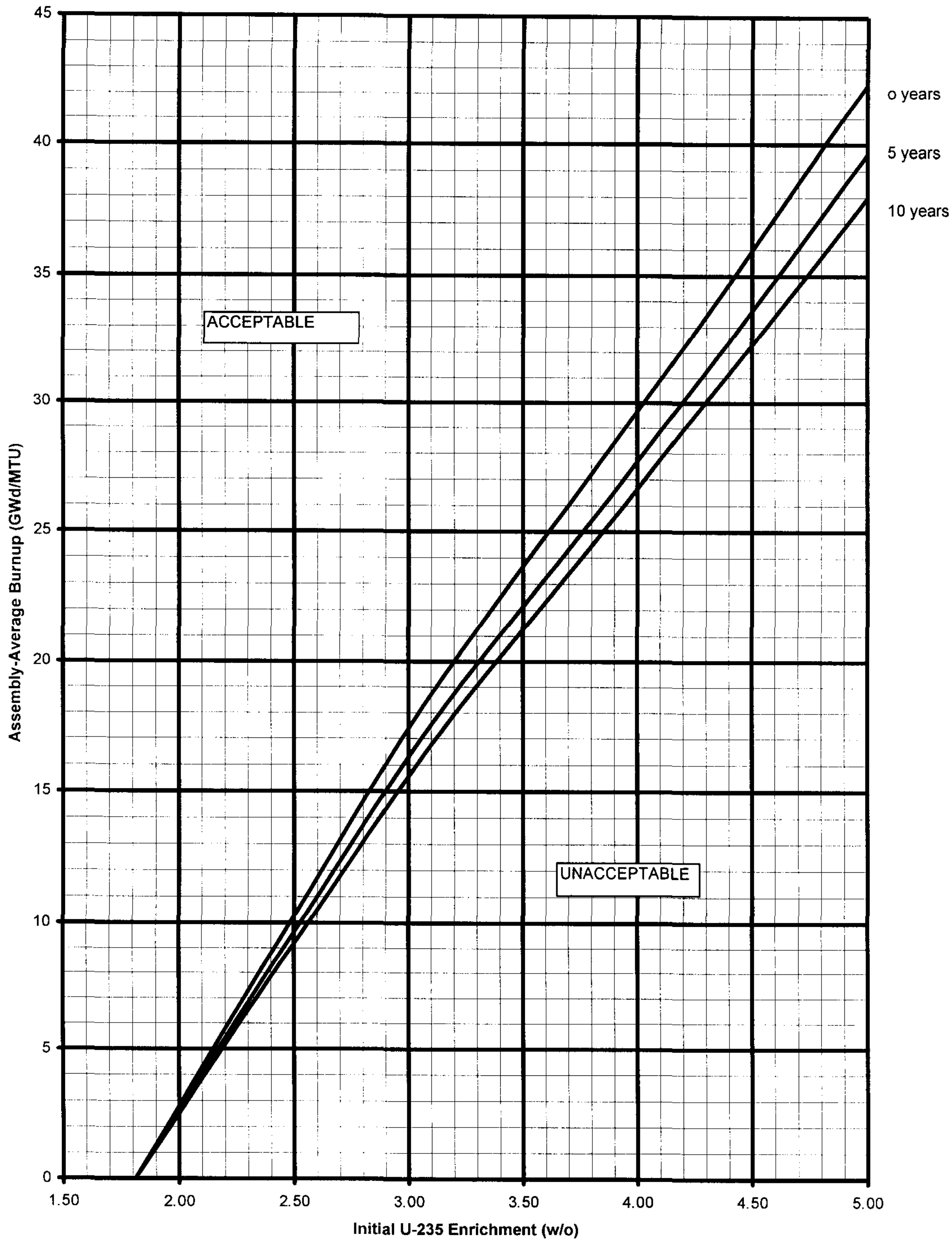
RESPONSE TO RAI QUESTIONS 21 and 24

REGARDING THE SPENT FUEL POOL LICENSE AMENDMENT REQUEST

UPDATED FIGURE 3.9-3 AND FIGURE 3.9-5

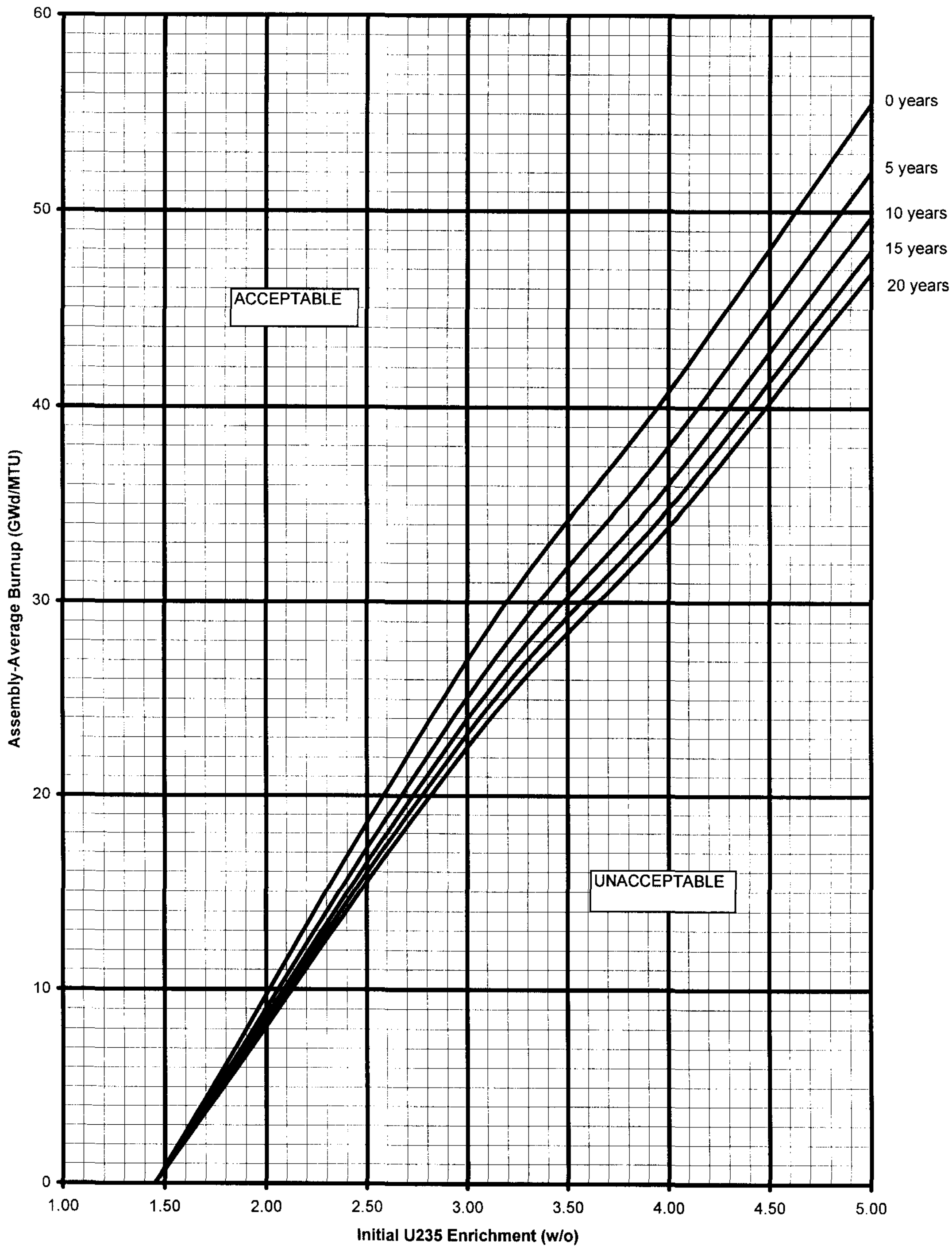
DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 3

Figure 3.9-3 Minimum Fuel Assembly Burnup and Decay Time Versus Nominal Initial Enrichment for Region 2 Storage Configuration



NOTE: For assemblies from Post-Uprate (3650 MWt) Cores, the nominal fuel enrichment of blankets must be ≤ 2.6 w/o U-235, and nominal blanket length must be at least 6 inches on both ends of the fuel.

Figure 3.9-5 Minimum Fuel Assembly Burnup and Decay Time Versus Nominal Initial Enrichment for Region 3 Storage Configuration for Assemblies from Post-Uprate (3650 MWt) Cores



NOTE: For assemblies from Post-Uprate (3650 MWt) Cores, the nominal fuel enrichment of blankets must be ≤ 2.6 w/o U-235, and nominal blanket length must be at least 6 inches on both ends of the fuel.