INDEX

LIMITING CONDITIONS FOR OPERATION AND SURVEILLANCE REQUIREMENTS

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LIMITING CONDITIONS FOR OPERATION AND SURVEILLANCE REQUIREMENTS

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3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

LIMITING CONDITION FOR OPERATION

3.9.12 Fuel is to be stored in the spent storage pool with:

a. The boron concentration in the spent fuel pool maintained at greater than or equal to 2000 ppm; and

b. Storage in Region 2 restricted to irradiated fuel which has decayed at least 16 days and one of the following:

1) fuel which has been qualified in accordance with Table 3.9-1; or

2) Fuel which has been qualified by means of an analysis using NRC approved methodology to assure with a 95 percent probability at a 95 percent confidence level that k_{eff} is no greater than 0.95 including all uncertainties; or

3) Unqualified fuel stored in a checkerboard configuration. In the event checkerboard storage is used, one row between normal storage locations and checkerboard storage locations will be vacant.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined a fuel assembly has been placed in the incorrect Region until such time as the correct storage location is determined. Move the assembly to its correct location before resumption of any other fuel movement.

b. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined the pool boron concentration is less than 2000 ppm, until such time as the boron concentration is increased to 2000 ppm or greater.

c. The provisions of Specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

4.9.12a. Verify all fuel assemblies to be placed in Region 2 of the spent fuel pool are within the enrichment and burnup limits of Table 3.9-1 or that $k_{eff} \leq 0.95$ by checking the assemblies' design and burnup documentation or the assemblies' qualifying analysis documentation respectively.

b. Verify at least once per 31 days that the spent fuel pool boron concentration is greater than 2000 ppm.

delete this page

3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

LIMITING CONDITION FOR OPERATION

3.9.12 Fuel is to be stored in the spent storage pool with:

a. The boron concentration in the spent fuel pool maintained at greater than or equal to 2175 ppm; and

b. Storage in Region 2 restricted to irradiated fuel which has decayed at least 16 days and one of the following:

1) fuel which has been qualified in accordance with Table 3.9-1; or

2) Fuel which has been qualified by means of an analysis using NRC approved methodology to assure with a 95 percent probability at a 95 percent confidence level that k_{eff} is no greater than 0.95 including all uncertainties; or

3) Unqualified fuel stored in a checkerboard configuration. In the event checkerboard storage is used, one row between normal storage locations and checkerboard storage locations will be vacant.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined a fuel assembly has been placed in the incorrect Region until such time as the correct storage location is determined. Move the assembly to its correct location before resumption of any other fuel movement.

b. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined the pool boron concentration is less than 2175 ppm, until such time as the boron concentration is increased to 2175 ppm or greater.

c. The provisions of Specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS

4.9.12a. Verify all fuel assemblies to be placed in Region 2 of the spent fuel pool are within the enrichment and burnup limits of Table 3.9-1 or that $k_{eff} \leq 0.95$ by checking the assemblies' design and burnup documentation or the assemblies' qualifying analysis documentation respectively.

b. Verify at least once per 31 days that the spent fuel pool boron concentration is greater than 2175 ppm.

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Table 3.9-1

Minimum Burnup Versus Initial Enrichment for Region 2 Storage

Initial Enrichment w/o U-235	Assembly Burnup (GWD/MT)
1.4	0.00
1.5	2.50
1.6	5.00
1.7	6.65
1.8	8.30
1.9	9.95
2.0	11.60
2.1	13.20
2.2	14.60
2.3	16.00
2.4	17.40
2.5	18.80
2.6	20.20
2.7	21.40
2.8	22.60
2.9	23.90
3.0	25.20
3.1	26.60
3.2	27.80
3.3	28.93
3.4	30.07
3.5	31.20
3.6	32.26
3.7	33.32
3.8	34.38
3.9	35.44
4.0	36.50

REFUELING OPERATIONS

3/4.9.12 SPENT FUEL POOL BORON CONCENTRATION

add new 3/4.9.12 replaces old 3/4.9.12

LIMITING CONDITION FOR OPERATION

3.9.12 The boron concentration in the spent fuel pool shall be within the limit specified in the COLR.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Immediately suspend movement of fuel assemblies in the spent fuel pool and initiate action to restore the spent fuel pool boron concentration to within its limit.

b. The provisions of Specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS:

4.9.12 Verify at least once per 31 days that the spent fuel pool boron concentration is within its limit.

3/4.9.13 SPENT FUEL ASSEMBLY STORAGE

add new 3/4.9.13

LIMITING CONDITION FOR OPERATION

3.9.13 Storage of new or irradiated fuel is limited to the configurations described in this specification.

a. New or irradiated fuel may be stored in Region 1 of the Spent Fuel Pool in accordance with these limits:

1) Unrestricted storage of fuel meeting the criteria of Table 3.9-1; or

2) Restricted storage in accordance with Figure 3.9-1, of fuel which does not meet the criteria of Table 3.9-1; or

3) Another configuration determined to be acceptable by means of an analysis to ensure that k_{eff} is less than or equal to 0.95.

b. New or irradiated fuel which has decayed at least 16 days may be stored in Region 2 of the Spent Fuel Pool in accordance with these limits:

1) Unrestricted storage of fuel meeting the criteria of Table 3.9-3; or

2) Restricted storage in accordance with Figure 3.9-2, of fuel which meets the criteria of Table 3.9-4; or

3) Checkerboard storage in accordance with Figure 3.9-3 of fuel which does not meet the criteria of Table 3.9-4; or

4) Another configuration determined to be acceptable by means of an analysis to ensure that k_{eff} is less than or equal to 0.95.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Immediately initiate action to move the non complying fuel assembly to the correct location.

b. The provisions of Specification 3.0.3 are not applicable.

add new 3/4.9.13

SURVEILLANCE REQUIREMENTS:

4.9.13 Prior to storing a fuel assembly in the spent fuel storage pool, verify by administrative means the initial enrichment and burnup of the fuel assembly are in accordance with Specification 3.9.13.

Table 3.9-1

Minimum Qualifying Burnup Versus Initial Enrichment for Unrestricted Region 1 Storage

add to 3/4.9.13

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
4.19 (or less)	0
4.20	0.04
4.50	1.92
4.75	3.40

Table 3.9-2

Minimum Qualifying Burnup Versus Initial Enrichment for Region 1 Filler Assemblies

add new 3/4.9.13

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.92 (or less)	0
3.00	1.57
3.50	13.30
4.00	18.32
4.50	23.36
4.75	25.84

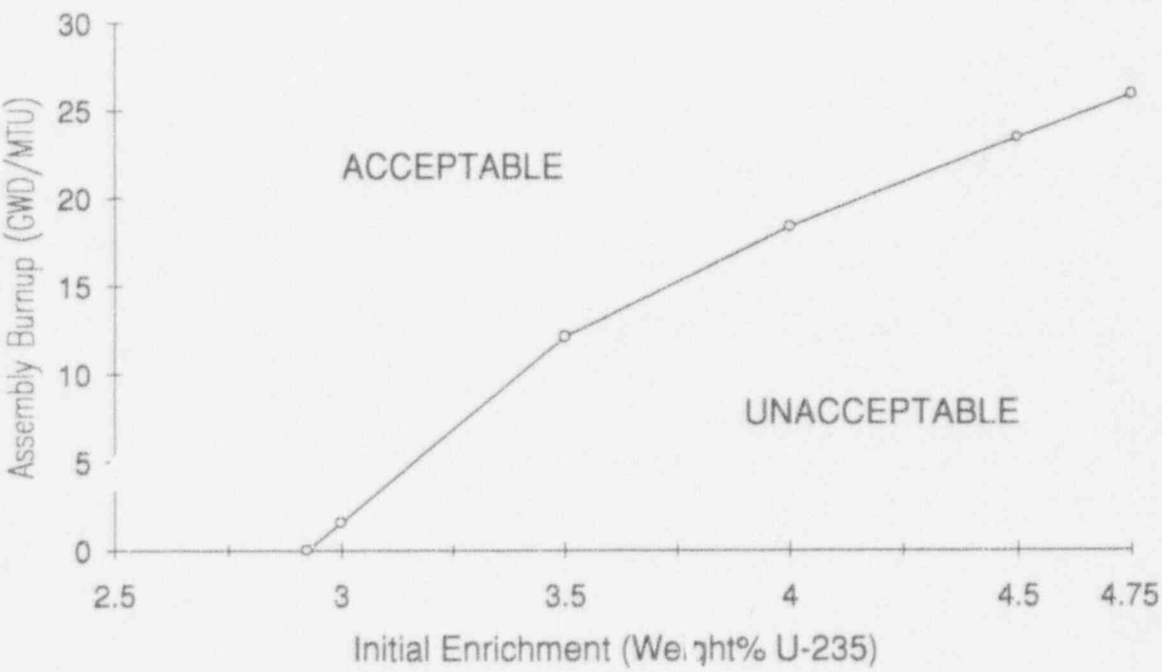


Table 3.9-3

Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 2 Storage

add to 3/4.9.13

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	10.54
2.50	17.96
3.00	24.64
3.50	30.86
4.00	36.75
4.50	42.38
4.75	45.10

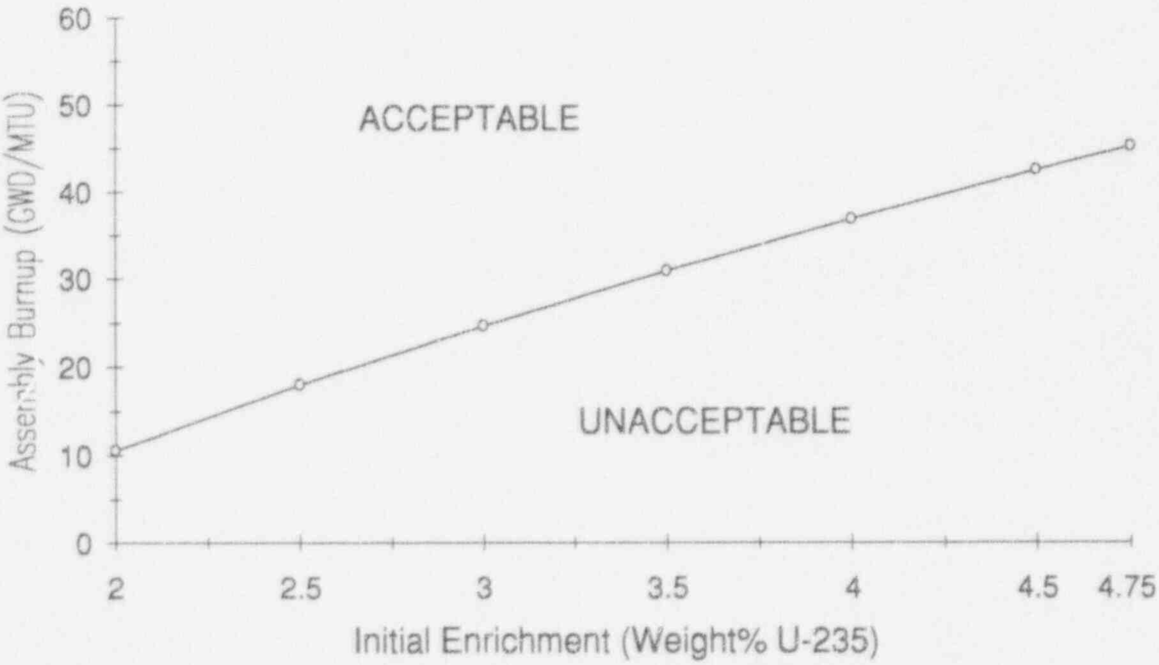
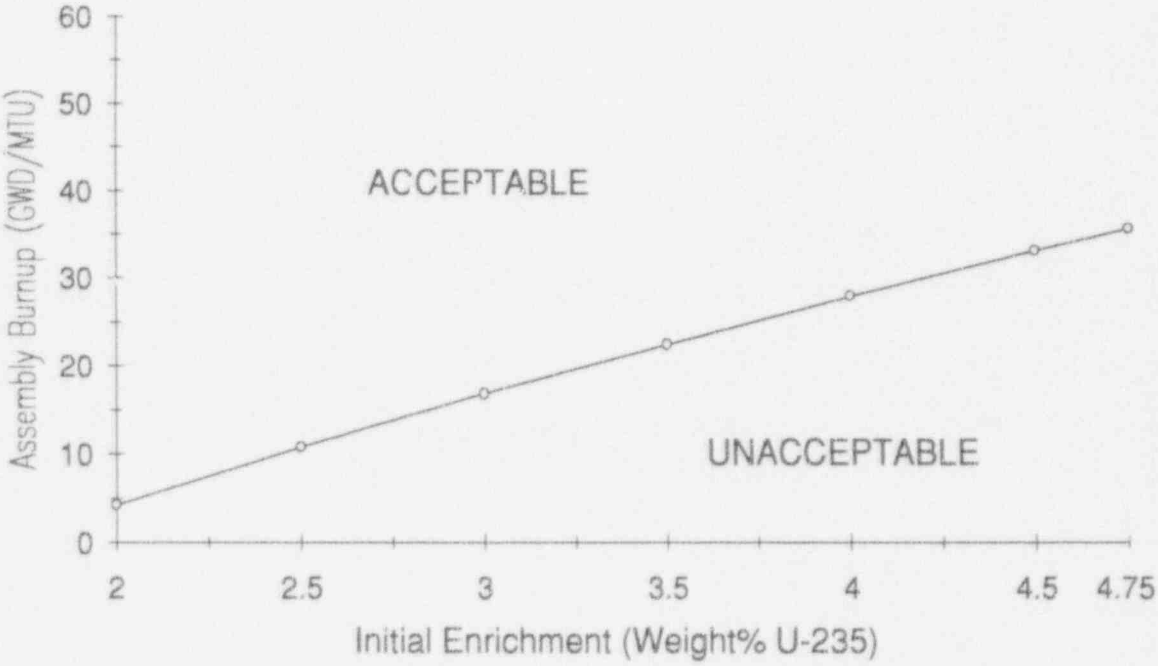


Table 3.9-4

Minimum Qualifying Burnup Versus Initial Enrichment for Restricted Region 2 Storage with Fillers

add to 3/4.9.13

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	4.22
2.50	10.75
3.00	16.80
3.50	22.41
4.00	27.92
4.50	33.14
4.75	35.65

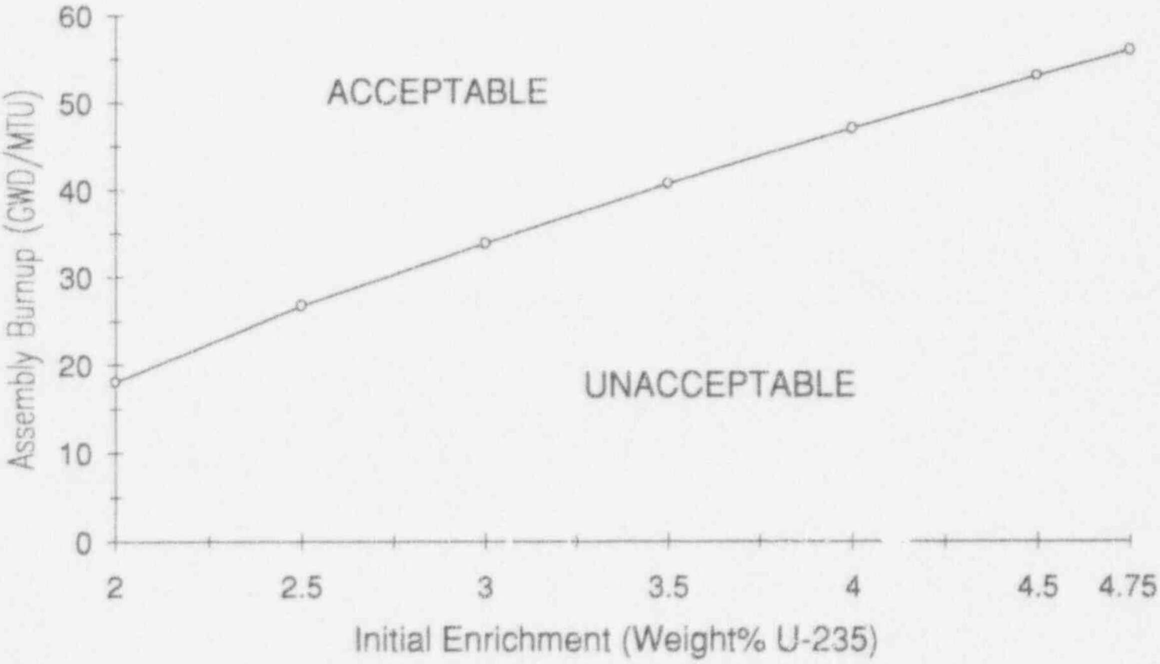


add to 3/4.9.13

Table 3.9-5

Minimum Qualifying Burnup Versus Initial Enrichment for Region 2 Filler Assemblies

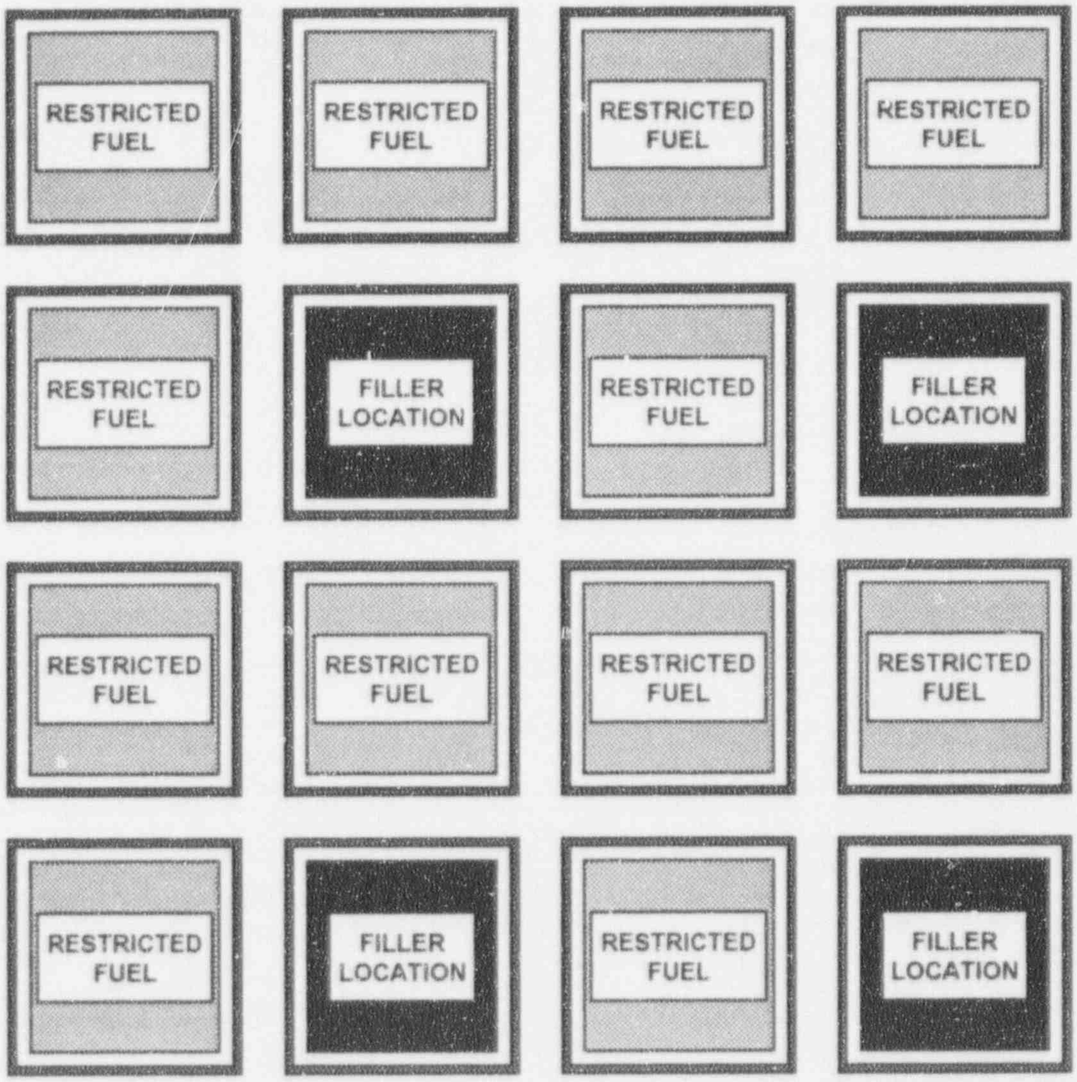
Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	18.03
2.50	26.71
3.00	33.79
3.50	40.56
4.00	46.83
4.50	52.86
4.75	55.78



add to 3/4.9.13

Figure 3.9-1

Required 3 out of 4 Loading Pattern for Restricted Region 1 Storage



Restricted Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.9-1. (Fuel which does meet the requirements of Table 3.9-1 may be placed in restricted fuel locations as needed)

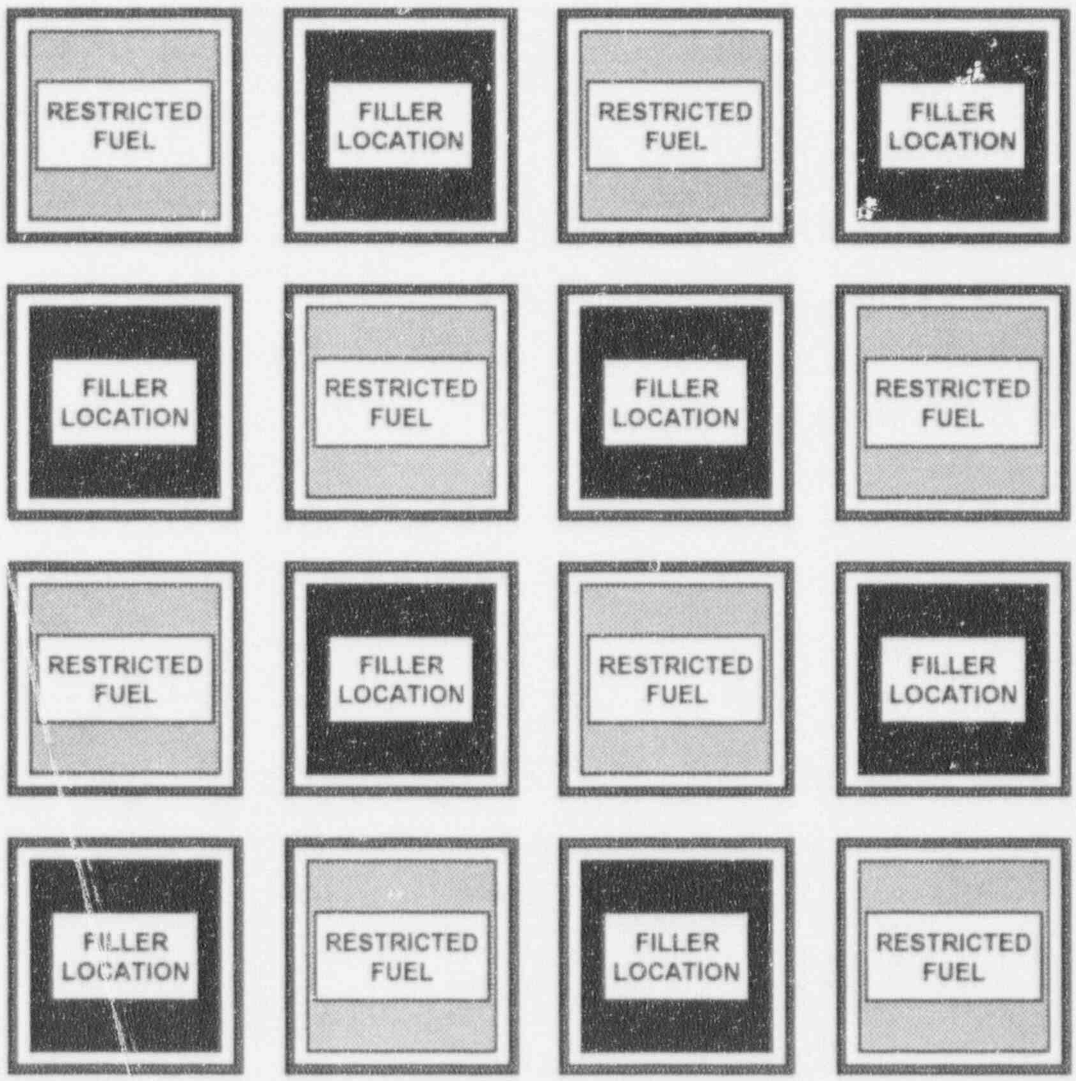
Filler Location: Either fuel which meets the minimum burnup requirements of Table 3.9-2, or an empty cell.

Boundary Condition: Any row bounded by a Region 1 Unrestricted Storage Area shall contain a combination of restricted fuel assemblies and filler locations arranged such that no restricted fuel assemblies are adjacent to each other.
Example: In the figure above, row 1 or column 1 can not be adjacent to a Region 1 Unrestricted Storage Area, but row 4 or column 4 can be.

add to 3/4.9.13

Figure 3.9-2

Required 2 out of 4 Loading Pattern for Restricted Region 2 Storage

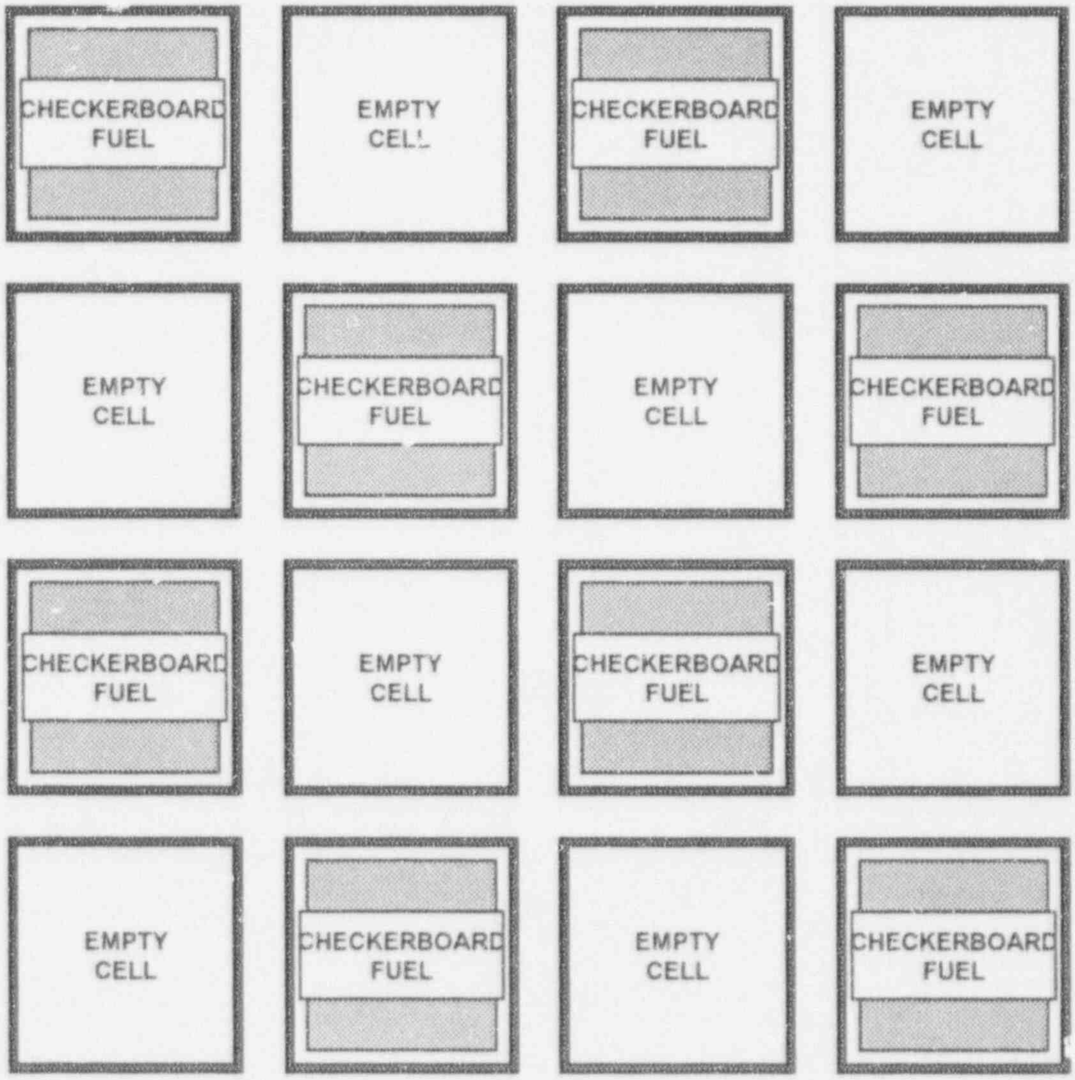


Restricted Fuel:	Fuel which meets the minimum burnup requirements of Table 3.9-4.
Filler Location:	Either fuel which meets the minimum burnup requirements of Table 3.9-5, or an empty cell.
Boundary Condition:	No restrictions on boundary assemblies.

add to 3/4.9.13

Figure 3.9-3

Required 2 out of 4 Loading Pattern for Checkerboard Region 2 Storage



Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.9-4. (Fuel which does meet the requirements of Table 3.9-4 may be placed in checkerboard fuel locations as needed)

Boundary Condition: At least two opposite sides shall be bounded by either an empty row of cells, or a spent fuel pool wall.

delete reference to unit

3/4.9.9 and 3/4.9.10 WATER LEVEL - REACTOR VESSEL and STORAGE POOL

The restrictions on minimum water level ensure that sufficient water depth is available to remove 99% of the assumed 10% iodine gap activity released from the rupture of an irradiated fuel assembly. The minimum water depth is consistent with the assumptions of the accident analysis.

3/4.9.11 FUEL HANDLING VENTILATION EXHAUST SYSTEM

The limitations on the Fuel Handling Ventilation Exhaust System ensure that all radioactive material released from an irradiated fuel assembly will be filtered through the HEPA filters and charcoal adsorbers prior to discharge to the atmosphere. The OPERABILITY of this system and the resulting iodine removal capacity are consistent with the assumptions of the accident analyses. ANSI N510-1975 will be used as a procedural guide for surveillance testing. The methyl iodide penetration test criteria for the carbon samples have been made more restrictive than required for the assumed iodine removal in the accident analysis because the humidity to be seen by the charcoal adsorbers may be greater than 70% under normal operating conditions.

3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

The requirements for fuel storage in the spent fuel pool on 3.9.12 (a) and (b) ensure that: (1) the spent fuel pool will remain subcritical during fuel storage; and (2) a uniform boron concentration is maintained in the water volume in the spent fuel pool for reactivity control. The value of 0.95 or less for Keff which includes all uncertainties at the 95/95 probability/ confidence level as described in Section 9.1.2.3.1 of the FSAR is the acceptance criteria for fuel storage in the spent fuel pool. Table 3.9-1 is conservatively developed in accordance with the acceptance criteria and methodology referenced in Section 5.6 of the Technical Specifications. Storage in a checkerboard configuration in Region 2 meets all the acceptance criteria referenced in Section 5.6 of the Technical Specifications and is verified in a semi-annual basis after initial verification through administrative controls.

The Action Statement applicable to fuel storage in the spent fuel pool ensures that: (1) the spent fuel pool is protected from distortion in the fuel storage pattern that could result in a critical array during the movement of fuel; and (2) the boron concentration is maintained at 2000 ppm during all actions involving movement of fuel in the spent fuel pool.

The Surveillance Requirements applicable to fuel storage in the spent fuel pool ensure that: (1) fuel stored in Region 2 meets the enrichment and burnup limits of Table 3.9-1 or the $K_{eff} \leq 0.95$ acceptance criteria of an analysis using NRC approved methodology; and (2) the boron concentration meets the 2000 ppm limit.

delete this section/ replace with attached BASES for 3/4.9.12 + 3/4.9.13 units 1 & 2

BASES

3/4.9.9 and 3/4.9.10 WATER LEVEL - REACTOR VESSEL and STORAGE POOL

The restrictions on minimum water level ensure that sufficient water depth is available to remove 99% of the assumed 10% iodine gap activity released from the rupture of an irradiated fuel assembly. The minimum water depth is consistent with the assumptions of the accident analysis.

3/4.9.11 FUEL HANDLING VENTILATION EXHAUST SYSTEM

The limitations on the Fuel Handling Ventilation Exhaust System ensure that all radioactive material released from an irradiated fuel assembly will be filtered through the HEPA filters and charcoal adsorbers prior to discharge to the atmosphere. The OPERABILITY of this system and the resulting iodine removal capacity are consistent with the assumptions of the accident analyses. ANSI N510-1975 will be used as a procedural guide for surveillance testing. The methyl iodide penetration test criteria for the carbon samples have been made more restrictive than required for the assumed iodine removal in the accident analysis because the humidity to be seen by the charcoal adsorbers may be greater than 70% under normal operating conditions.

3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

The requirements for fuel storage in the spent fuel pool on 3.9.12 (a) and (b) ensure that: (1) the spent fuel pool will remain subcritical during fuel storage; and (2) a uniform boron concentration is maintained in the water volume in the spent fuel pool for reactivity control. The value of 0.95 or less for Keff which includes all uncertainties at the 95/95 probability/ confidence level as described in Section 9.1.2.3.1 of the FSAR is the acceptance criteria for fuel storage in the spent fuel pool. Table 3.9-1 is conservatively developed in accordance with the acceptance criteria and methodology referenced in Section 5.6 of the Technical Specifications. Storage in a checkerboard configuration in Region 2 meets all the acceptance criteria referenced in Section 5.6 of the Technical Specifications and is verified in a semi-annual basis after initial verification through administrative controls.

The Action Statement applicable to fuel storage in the spent fuel pool ensures that: (1) the spent fuel pool is protected from distortion in the fuel storage pattern that could result in a critical array during the movement of fuel; and (2) the boron concentration is maintained at 2175 ppm during all actions involving movement of fuel in the spent fuel pool.

The Surveillance Requirements applicable to fuel storage in the spent fuel pool ensure that: (1) fuel stored in Region 2 meets the enrichment and burnup limits of Table 3.9-1 or the $K_{eff} \le 0.95$ acceptance criteria of an analysis using NRC approved methodology; and (2) the boron concentration meets the 2175 ppm limit.

delete this section and associated unit 2 reference

3/4.9.12 and 3/4.9.13 SPENT FUEL POOL BORON CONCENTRATION and SPENT FUEL ASSEMBLY STORAGE

The requirements for spent fuel pool boron concentration specified in Specification 3.9.12 ensure that a minimum boron concentration is maintained in the pool. The requirements for spent fuel assembly storage specified in Specification 3.9.13 ensure that the pool remains subcritical. The water in the spent fuel storage pool normally contains soluble boron, which results in large subcriticality margins under actual operating conditions. However, the NRC guidelines based upon the accident condition in which all soluble poison is assumed to have been lost, specify that the limiting k_{eff} of 0.95 be evaluated in the absence of soluble boron. Hence the design of the spent fuel storage racks is based on the use of unborated water, which maintains each region in a subcritical condition during normal operation with the spent fuel pool fully loaded. The double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) allows credit for soluble boron under other abnormal or accident conditions, since only a single accident need be considered at one time. For example, the most severe accident scenario is associated with the movement of fuel from Region 1 to Region 2, and accidental misloading of a fuel assembly in Region 1 or Region 2. This could increase the reactivity of the spent fuel pool. To mitigate these postulated criticality related accidents, boron is dissolved in the pool water.

Specification 3.9.13.a.3 and 3.9.13.b.4 allow for specific criticality analysis for configurations other than those explicitly defined in Specification 3.9.13. These analyses would require using NRC approved methodology to ensure that $k_{eff} \leq 0.95$ with a 95 percent probability at a 95 percent confidence level as described in Section 9.1 of the FSAR.

In verifying the design criteria of $k_{eff} \leq 0.95$, the criticality analysis assumed the most conservative conditions, i.e. fuel of the maximum permissible reactivity for a given configuration. Since the data presented in Specification 3.9.13.a and 3.9.13.b represents the maximum reactivity requirements for acceptable storage, substitutions of less reactive components would also meet the $k_{eff} \leq 0.95$ criteria. Hence, any non-fuel component may be placed in a designated empty cell location. Likewise, an empty cell, or a non-fuel component may be substituted for any designated fuel assembly location. These, or other substitutions which will decrease the reactivity of a particular storage cell will only decrease the overall reactivity of the spent fuel storage pool.

If both restricted and unrestricted storage is used in Region 1, an additional criteria has been imposed to ensure that the boundary row between these two configurations would not locally increase the reactivity above the required limit. Likewise if checkerboard storage is used in Region 2, an additional restriction has been imposed on the boundaries of the checkerboard storage region to ensure that the reactivity would not increase above the required limit. No other restrictions on region interfaces are necessary.

For storage in Region 2 requiring loading pattern restrictions, (per Specifications 3.9.13.b.2 or 3.9.13.b.3) fuel may be stored in either the "cell" or "non-cell" locations.

"Cell" locations are the areas inside the fabricated storage cells and "non-cell" locations are the storage locations created by arranging the fabricated storage cells in a checkerboard configuration. Hence the "non-cell" locations are the areas defined by the outside walls of the 4 adjacent "cell" locations.

The action statement applicable to fuel storage in the spent fuel pool requires that action must be taken to preclude the occurrence of an accident or to mitigate the consequences of an accident in progress. This is most efficiently achieved by immediately suspending the movement of fuel assemblies. Prior to the resumption of fuel movement, the requirements of the LCOs must be met. This requires restoring the soluble boron concentration and the correct fuel storage configuration to within the corresponding limits. This does not preclude movement of a fuel assembly to a safe position.

The surveillance requirements ensure that the requirements of the two LCOs are satisfied, namely boron concentration and fuel placement. The boron concentration in the spent fuel pool is verified to be greater than or equal to the minimum limit. The fuel assemblies are verified to meet the subcriticality requirement by meeting either the initial enrichment and burnup requirements of Table 3.9-1 through 3.9-5, or by using NRC approved methodology to ensure that $k_{eff} \leq 0.95$. By meeting either of these requirements, the analyzed accidents are fully addressed.

The fuel storage requirements and restrictions discussed here and applied in section 3.9.13 are based on a maximum allowable fuel enrichment of 4.75 weight% U-235. The enrichments listed in Tables 3.9-1 through 3.9-5 are nominal enrichments and include uncertainties to account for the tolerance on the as built enrichment. Hence the as built enrichments may exceed the enrichments listed in the tables by up to 0.05 weight% U-235. Qualifying burnups for enrichments not listed in the tables may be linearly interpolated between the enrichments provided. This is because the reactivity of an assembly varies linearly for small ranges of enrichment.

REFERENCES

1. "Regulatory Guide 1.13: Spent Fuel Storage Facility Design Basis", U.S. Nuclear Regulatory Commission, Office of Standards Development, Revision 1, December 1976.

2 "Design Objectives for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations", American Nuclear Society, ANSI N210-1976/ANS-57.2, April 1976.

3. FSAR, Section 9.1.

4. Double contingency principle of ANSI N16.1-1975, as specified in the April 14, 1978 NRC letter (Section 1.2) and implied in the proposed revision to Regulatory Guide 1.13 (Section 1.4, Appendix A).

5.4 REACTOR COOLANT SYSTEM

DESIGN PRESSURE AND TEMPERATURE

5.4.1 The Reactor Coolant System is designed and shall be maintained:

a. In accordance with the Code requirements specified in Section 5.2 of the FSAR, with allowance for normal degradation pursuant to the applicable Surveillance Requirements,

b. For a pressure of 2485 psig, and

c. For a temperature of 650°F, except for the pressurizer which is 680°F.

VOLUME

5.4.2 The total water and steam volume of the Reactor Coolant System is 12,040 ± 100 cubic feet at a nominal T_{avg} of 525°F.

5.5 METEOROLOGICAL TOWER LOCATION

5.5.1 The meteorological tower shall be located as shown on Figure 5.1-1.

5.6 FUEL STORAGE

CRITICALITY

5.6.1 The new and spent fuel storage racks are designed and shall be maintained with:

a. A k_{eff} equivalent to less than or equal to 0.95 when flooded with unborated water, which includes a conservative allowance for uncertainties as described in Section 9.1.2.3.1 of the FSAR, and

b. A nominal 21-inch center-to-center distance between fuel assemblies placed in the new fuel storage vault racks, and

c. A nominal 10.4-inch and 9.125-inch center-to-center distance between fuel assemblies placed in Region 1 and Region 2 storage racks, respectively, in the spent fuel storage pool.

delete this section/ replace with new 5.6.1

DRAINAGE

5.6.2 The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 745 ft. 7 in.

CAPACITY

5.6.3 The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1463 fuel assemblies (286 spaces in Region 1 and 1177 spaces in Region 2) having an initial enrichment less than or equal to 4.0 weight percent U-235.

replaces old 5.6.1

5.6 Fuel Storage

CRITICALITY

5.6.1 a. The spent fuel storage racks are designed and shall be maintained with $k_{eff} \leq 0.95$ if fully flooded with unborated water as described in Section 9.1 of the FSAR; and

b. The new fuel storage racks are designed and shall be maintained with $k_{eff} \leq 0.95$ if fully flooded with unborated water; and $k_{eff} \leq 0.98$ if moderated by aqueous foam as described in Section 9.1 of the FSAR.

DRAINAGE

5.6.2 The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 745 ft. 7 in.

CAPACITY

5.6.3 The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1463 fuel assemblies (286 spaces in Region 1 and 1177 spaces in Region 2).

ATTACHMENT II
NO SIGNIFICANT HAZARDS ANALYSIS

Duke Power Company has reviewed the proposed changes utilizing the criteria specified in 10CFR50.92 and has determined that the proposed changes do not involve a Significant Hazards Consideration pursuant thereto, for the reasons discussed below.

1. The proposed changes do not involve a significant increase in the probability or consequences of an accident previously evaluated.

There is no increase in the probability or consequences of an accident in the new fuel vault since the only credible accidents for this area are criticality accidents and it has been shown that calculated, worst case K_{eff} for this area is ≤ 0.95 under all conditions.

There is no increase in the probability of a fuel drop accident in the Spent Fuel Storage Pool since the mass of an assembly will not be affected by the increase in fuel enrichment. The likelihood of other accidents, previously evaluated and described in Section 9.1.2 of the FSAR, is also not affected by the proposed changes. In fact, it could be postulated that since the increase in fuel enrichment will allow for extended fuel cycles, there will be a decrease in fuel movement and the probability of an accident may likewise be decreased. There is also no increase in the consequences of a fuel drop accident in the Spent Fuel Pool since the fission product inventory of individual fuel assemblies will not change significantly as a result of increased initial enrichment. In addition, no change to safety related systems is being made. Therefore, the consequences of a fuel rupture accident remain unchanged. Also, it has been shown that k_{eff}, is ≤ 0.95, under all conditions therefore, the consequences of a criticality accident remain unchanged as well.

2. The proposed changes do not create the possibility of a new or different kind of accident from any accident previously evaluated.

The proposed changes do not create the possibility of a new or different kind of accident since fuel handling accidents(fuel drop and misplacement) are not new or different kinds of accidents. Fuel handling accidents are already discussed in the FSAR for fuel with enrichments up to 4.1 weight %. As described in Section VI.9 of Attachment IV, additional analyses have been performed for fuel with enrichment up to 4.75 weight %. Worst case misloading accidents associated with the new loading patterns were evaluated. For all possible misloading accidents the negative reactivity provided by soluble boron maintains $k_{eff} \leq 0.95$.

3. The proposed changes do not involve a significant reduction in the margin of safety.

The proposed change does not involve a significant reduction in the margin of safety since, in all cases, a $k_{eff} \leq 0.95$ is being maintained. Criticality analyses have been performed which show that the new fuel storage vault will remain subcritical under a variety of moderation conditions, from fully flooded to optimum moderation. As discussed above, the Spent Fuel Pool will remain sufficiently subcritical during any fuel misplacement accident.

ATTACHMENT III
ENVIRONMENTAL IMPACT ANALYSIS

Pursuant to 10CFR51.22 (b), an evaluation of the proposed amendments has been performed to determine whether or not it meets the criteria for categorical exclusion set forth in 10CFR51.22 (c)9 of the regulations. The proposed amendment does involve changes in the use of facility components located within the restricted area as defined in 10CFR20, and changes some surveillance requirements however, the proposed amendment does not involve:

1) A significant hazards consideration.

As discussed in Attachment II of this submittal, the proposed amendments do not involve an unresolved safety question since the changes do not; 1) Increase the probability or consequences of an accident previously evaluated, 2) Create a new or different kind of accident than one previously evaluated, or 3) Involve a reduction in the margin of safety.

2) A significant change in the types or significant increase in the amounts of any effluents that may be released offsite.

An increase in the fuel enrichment limit or storage configuration would not change the types of effluents created since the use of that material is not being changed. The amounts of effluents to be released offsite also, would not be changed since, the inventory of fission products contributing to offsite dose would not be increased significantly with an increase in fuel enrichment or burnup, and the mechanisms used to control offsite releases are not being changed.

3) A significant increase in the individual or cumulative occupational radiation exposure.

Increases in individual or cumulative occupational exposure would not be expected with this change since no safety systems, or related procedural controls associated with the handling or storage of fuel are being changed. These safety controls ensure that sufficient water level is maintained in the pool to provide adequate radiation shielding and that $k_{eff} \leq 0.95$ under all storage conditions.

Attachment IV

Duke Power Company
McGuire Nuclear Station

Fuel Enrichment Upgrade

License Amendment Request
and
Supporting Safety Analysis

Table of Contents

I INTRODUCTION

This submittal represents Duke Power Company's formal request for approval of a license amendment which establishes several restricted loading patterns and associated burnup criteria for placement of new and irradiated fuel into both regions of the McGuire spent fuel storage pools. Analysis performed in support of this submittal demonstrates that the use of one or more of these configurations for storing fuel with initial enrichments of up to 4.75weight% (nominal) U-235 will maintain sufficient criticality safety margins. This amendment will allow for maximum utilization of the fuel storage racks and will provide additional flexibility in the area of reactor core analysis and design.

Also included as part of this submittal is a detailed description of the analytical methodology used to generate the various burnup criteria discussed above. This methodology was specifically developed for spent fuel burnup credit applications and is based on the CASMO and SIMULATE computer codes. Since it has not been previously used by Duke Power Company, formal approval of this methodology is also being sought with this application.

II BACKGROUND INFORMATION

The two unit McGuire Nuclear Station became fully operational in 1983. At that time the plant had a total spent fuel storage capacity of 1000 fuel assemblies utilizing a 15" center-to-center spacing between individual fuel assemblies in two independent spent fuel pools. The McGuire Nuclear Station was initially licensed with a maximum allowable fuel enrichment of 4.0weight% U-235 with an absolute tolerance of .05weight%. Since each reactor core design is individually licensed this limit is specifically applicable to the new fuel storage vaults and the spent fuel storage pools.

In 1985 and 1987, the unit 2 and unit 1 spent fuel storage pools were respectively reracked with eight free standing modules of storage cells totaling 1463 per pool. The majority of the storage cells are closely spaced to accommodate less reactive burned assemblies whereas the remaining cells are intended for the higher reactivity of new or partially burned fuel. This 2 region concept resulted in a considerable increase in the fuel storage capacity allowing for 10 or more years of additional discharge capability for each reactor unit. The burnup requirements for the burned fuel region (region 2) of the storage racks were defined by a single burnup versus enrichment curve. This curve is currently represented as table 3.9-1 in Technical Specification # 3/4.9.12. No increase in the maximum allowable enrichment was necessary or requested as part of the licensing approval for this rerack project.

In the 7 years since completing the rerack effort, the McGuire Station has permanently discharged a significant inventory of unqualified fuel assemblies which are currently stored w... the required checkerboard storage configuration in the region 2 area of the spent fuel pool. Additionally, plans are underway to utilize future reload batches which incorporate fuel assemblies with enrichments in excess of the current 4.0weight% limit. The continued generation of unqualified assemblies and the pending increase in fuel enrichments together represent the basis for this submittal.

III JUSTIFICATION

The primary reasons for this amendment request are to increase the efficiency of fuel storage cell utilization in the spent fuel pools and to provide additional flexibility to the reload design efforts at Duke.

The McGuire station is currently storing about 100 assemblies in the 50% checkerboard configuration which leaves over 100 storage cells unavailable for spent fuel storage. Additionally, under the current reload design configuration, each unit will discharge up to an additional 15 "unqualified" assemblies per cycle which will require the same 50% checkerboard storage configuration. The combination of the current and the projected unusable storage cells will force the McGuire nuclear station to install additional spent fuel storage capacity 2 to 3 years earlier than would otherwise be necessary with these cells being available for fuel storage.

Preliminary studies have indicated dry storage to be the most likely alternative for providing additional on-site storage capacity as the McGuire pools approach full capacity. Based on current discharge projections, Duke will be forced to install additional capacity at McGuire by the year 2000. Experience at Duke's Oconee Nuclear Station shows that expenditures of up to $12 Million would be necessary to initiate such a facility with annual costs being in the range of $2 million. Delaying these startup and annual costs by freeing up current and projected unavailable storage cells would represent significant economic savings for Duke Power Company. Additionally, once the storage facility is operational, the ongoing generation of "unqualified" assemblies requiring 50% storage would force an accelerated annual rate of fuel movement into the storage facility, representing additional economic penalties.

From the standpoint of reload design, Duke continuously performs extensive economic sensitivity studies to evaluate variations in cycle length, reload batch size, and reload batch enrichments. Duke's ongoing goal is to develop the most efficient core designs for each operating cycle. Recent efforts in this area have indicated the desirability of a 459 EFPD cycle for both McGuire Units. Reload batches containing fuel with enrichments in the range of 4.10 to 4.75 weight% are being evaluated for these extended cycles.

IV SCHEDULE

Current plans for the earliest transition to the 459 EFPD cycle length are focusing on Unit 2, cycle 11 which is currently scheduled for a June, 1996 startup. Based on a one year lead time requirement for planning, detailed design, licensing, enrichment, and fabrication of fuel batches, approval of the higher enrichment capability for the McGuire facility would be needed by June, 1995 at the latest. A delayed approval of this amendment request beyond the middle of 1995 would force Duke Power to delay movement to this more economic 459 EFPD cycle length.

V. GENERAL DESCRIPTION OF AMENDMENT REQUEST/SUBMITTAL

V.1 Introduction

The primary purpose of this submittal is to demonstrate sufficient analytical justification for modifying technical specifications and FSAR sections currently applicable to new and irradiated fuel storage at the McGuire Nuclear Station (MNS). Areas proposed for modification are the limitations and restrictions associated with 1) storage of un-irradiated fuel in auxiliary building new fuel storage vaults, 2) storage of irradiated and un-irradiated fuel in the region 1 areas of both spent fuel pools, and 3) storage of irradiated and un-irradiated fuel in the region 2 areas of both spent fuel pools.

The fuel storage rack designs for the storage vaults and pools of both MNS units are identical. The spent fuel storage racks were designed and fabricated by Westinghouse and were installed in 1984 (unit 2) and 1986 (unit 1). Consequently all analytical methods and results discussed in this document are applicable to either unit as are the resulting procedural and technical specification modifications. Additionally, the most reactive of the fuel types applicable for each analyzed situation was used in developing the proposed requirements and limitations. Eventual approval of this amendment request should therefore apply to both units.

V.2 New Fuel Storage Vaults

The new fuel storage vaults which are used for temporary dry storage of un-irradiated reload fuel are built on 21 inch centers and are currently licensed for maximum fuel enrichments of 4.0weight% (nominal) U-235. To accommodate anticipated increases in individual and/or batch average enrichments that are likely to exceed this 4.0weight% limit, previously approved analytical methods were used to demonstrate that fuel containing up to 4.75 weight% (nominal) U-235 can be safely stored in these fuel racks. No other restrictions beyond this enrichment limit are applicable to storage in the new fuel vaults. Discussion of the methods used to justify this increased limit can be found in section VI.5 and the resulting proposed FSAR modifications can be found in section VIII.2. No technical specifications are applicable to the new fuel storage vaults.

V.3 Spent Fuel Storage Pools - Region 1

The basic spent fuel storage pool rack arrangement for units 1 and 2 is shown in figure 5-1 on the following page. The region 1 area of the pool is highlighted and a schematic of the region 1 cell configuration is also provided.

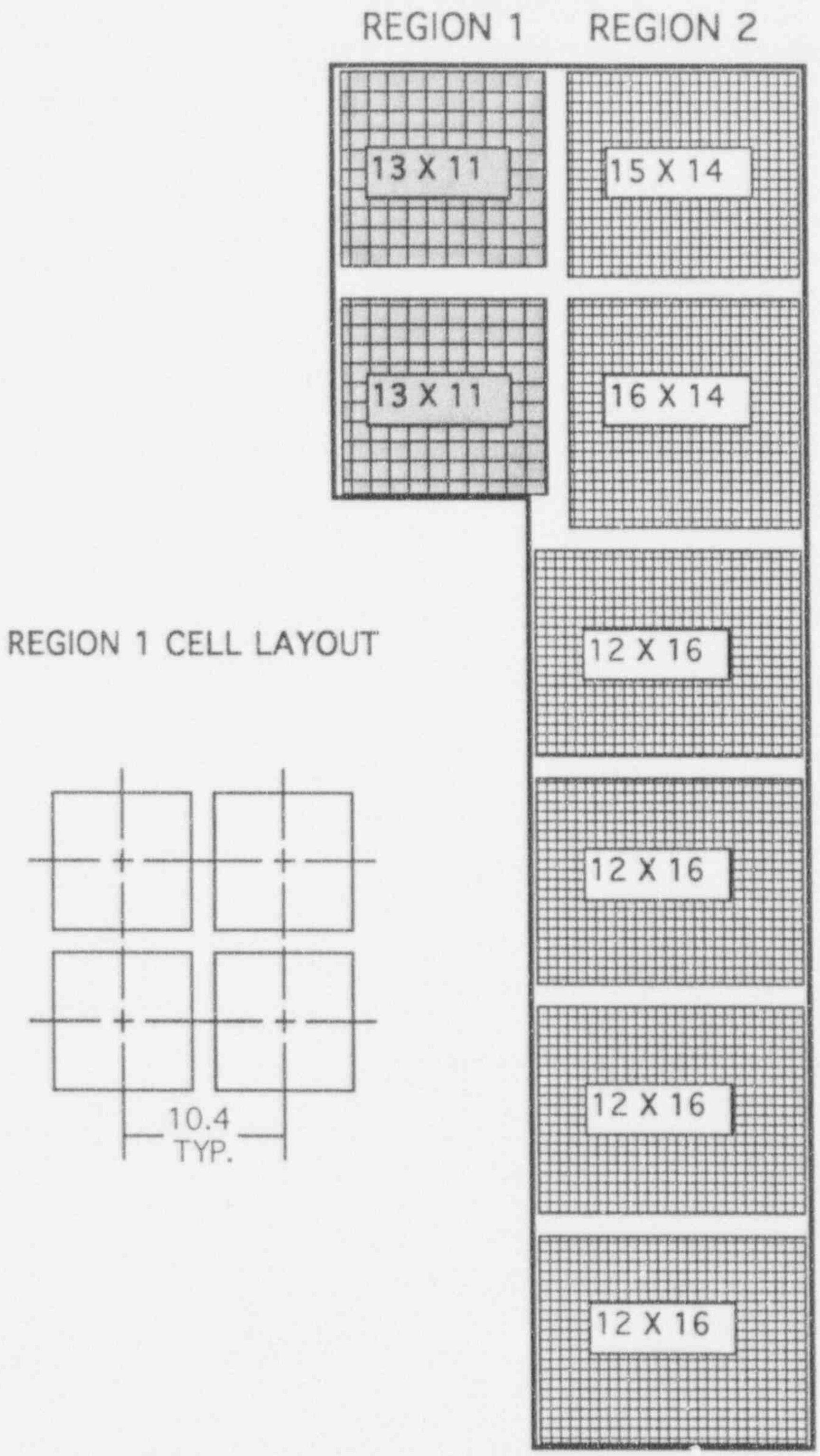


Figure 5-1
McGuire Fuel Pool Layout with Region I Detail

The region 1 area of the spent fuel pools is designed and generally reserved for temporary storage of new or partially irradiated fuel which would not qualify for storage in the region 2 area. The storage cell configuration in this region represents a less reactive array than that of region 2 (see section V.4). The stainless steel cells are spaced at 10.4 inches and utilize a .02 gm/cm^2 loading of B_{10} neutron absorbing material attached to the exterior cell wall wrapper plate. This region has a capacity (286 locations) which exceeds that needed to accommodate both a complete off load of the reactor core and storage of a reload fuel batch. As is the case with the new fuel vaults, the region 1 storage cells are limited analytically to fuel with a maximum initial enrichment of 4.0 weight %.

Unrestricted Storage

To accommodate the projected as-built fuel enrichment increases discussed in section III, the region 1 storage racks have been re-analyzed to allow for an increase in the maximum allowable initial enrichment of the stored fuel. This analysis allows for unrestricted storage (i.e. no limits on storage location or pattern) of new or irradiated fuel having initial enrichments up to 4.19 weight % (nominal).

Additional region 1 analysis was performed to develop burnup criteria for unrestricted storage of irradiated assemblies with initial enrichments in excess of the 4.19 weight % limit stated above. These criteria are summarized in section VII.2. Expressed as specific burnup vs. enrichment limits, these criteria were generated utilizing reactivity equivalencing (burnup credit) techniques similar to that used in the original amendment request associated with installing these fuel storage racks. An overview of the specific methodology developed by Duke Power Company for this application is provided in section VI.6. A more detailed generic discussion of this methodology is submitted with this application as Appendix B.

New or irradiated assemblies which meet the requirements for unrestricted storage in region 1 will be referred to as fuel category 1A throughout this submittal. New or irradiated assemblies which do not meet the above requirements for unrestricted storage in region 1, but do require temporary region 1 placement for operational requirements or per existing technical specification #3.9.12.b, must be placed in a restricted loading pattern. Restricted storage requirements for region 1 are discussed below. Proposed technical specifications governing the requirements for region 1 storage are included in section VIII.1.

Restricted Storage

In order to accommodate those assemblies (up to the proposed new fuel vault nominal limit of 4.75weight%) which do not qualify for unrestricted region 1 storage, criticality analysis was performed to identify a critically safe yet simple loading pattern restriction. While several configurations were considered, the loading pattern proposed utilizes very simple administrative control procedures and allows for maximum utilization of storage space in the spent fuel pools. Figure 5-2 on the following page illustrates the proposed storage restriction which limits storage of these unqualified assemblies to 3 of every 4 cells. Assemblies requiring placement into this storage configuration will be referred to as fuel category 1B throughout this submittal. Also shown is the requirement that the fourth location of this pattern contain an appropriately qualified "filler" assembly.

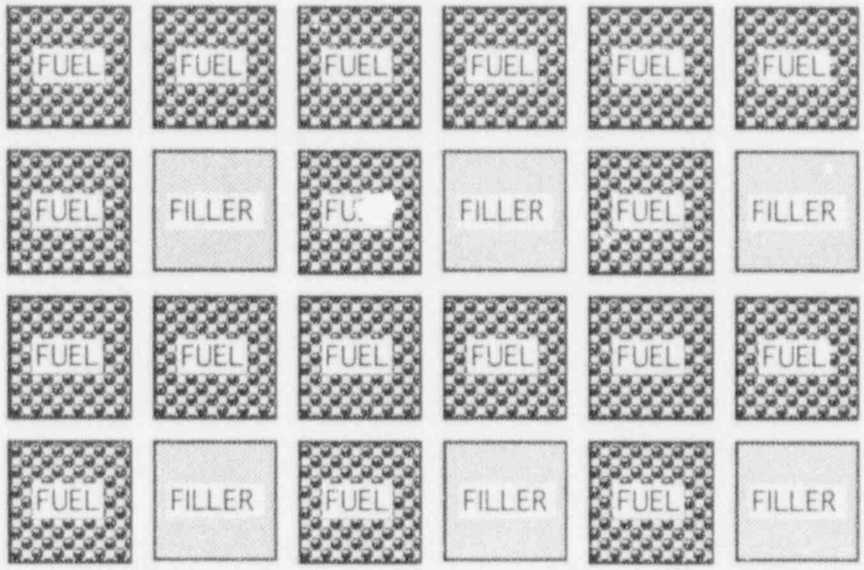


Figure 5-2
<u>Region 1 Restricted Storage Loading Pattern</u>

Discussion of the analysis which justifies the above loading pattern and the specific selection criteria for the filler assemblies is included in sections VI.6 and VII.2 respectively. Expressed as specific burnup vs. enrichment limits, these criteria were also generated using reactivity equivalencing (burnup credit) techniques and the specific methodology detailed in appendix B. Assemblies qualified for, and selected as fillers for region 1, will be referred to as fuel category $1B_f$ throughout this submittal. In the event that enough "filler" assemblies are not available for use, empty cells may be used in place of appropriately qualified filler assemblies.

To preclude a fuel mis-loading accident, an appropriate quantity of these filler assemblies will be in place in an appropriate portion of the region 1 storage area prior to placement of restricted/unqualified assemblies. This and other administrative controls are discussed further in section IX. Proposed technical specifications governing this and all other requirements for restricted region 1 storage are included in section VIII.1. A summary description of the various region 1 and region 2 fuel categories is provided below.

Fuel Category	Region	Fuel Category Description	Loading Restriction
1A	1	New or Irradiated fuel qualified for unrestricted region 1 storage	None
1B	1	New or Irradiated fuel requiring restricted region 1 storage	75% with empty cells or filler assemblies
$1B_f$	1	Irradiated fuel qualified for use as region 1 filler assemblies	Use for region 1 fillers
2A	2	Irradiated fuel qualified for unrestricted region 2 storage	None
2B	2	Irradiated fuel requiring restricted region 2 storage with fillers or empty cells	50% with empty cells or w/ filler assemblies
2C	2	Irradiated fuel requiring restricted region 2 storage with empty cells	50% checkerboard with empty cells
$2B_f$	2	Irradiated fuel qualified for use as region 2 filler assemblies	Use for region 2 fillers

V.4 Spent Fuel Storage Pools - Region 2

The basic spent fuel storage pool rack arrangement for units 1 and 2 is shown again in figure 5-3 on the following page with the region 2 area of the pool highlighted and a schematic of the region 2 cell configuration provided. The region 2 area of the spent fuel pools is designed and generally used for normal, long term storage of permanently discharged fuel that has achieved qualifying burnup levels. The storage cell configuration in this region represents a more reactive array than that of region 1. The stainless steel cells are assembled in a checkerboard pattern, producing a honeycomb structure of "cell" and "non-cell" locations as shown. This configuration has a much tighter center-to-center pitch of 9.125 inches. These cells also utilize a neutron absorbing material having a slightly lower B_{10} areal density (.006 gm/cm^2) than that used in region 1. This region has a nominal capacity of 1177 locations. As is the case with the new fuel vaults and region 1 area, the region 2 storage cells are analytically limited to a maximum initial enrichment of 4.0 weight % (nominal) at this time.

Unrestricted Storage

The region 2 area of the McGuire spent fuel pools was primarily designed/intended for unrestricted (i.e. 100% loading pattern) storage of irradiated fuel which has achieved a qualifying level of burnup per the guidelines of technical specification # 3.9.12b. Unqualified assemblies, when generated, must be stored in a restricted loading pattern. The current technical specification and supporting analysis addresses fuel having initial enrichments up to 4.0 weight% (nominal). This licensing submittal proposes a redefined set of qualification specifications which will allow for fuel assemblies having initial enrichments up to the proposed higher nominal limits of the new fuel vault (4.75 weight %).

Reactivity equivalencing (burnup credit) techniques similar to those used to identify the existing qualification requirements for unrestricted storage in this region of the spent fuel pools are used to redefine new qualification requirements for the proposed wider range of initial enrichments. Section VI.6 discusses the analysis performed and the resulting enrichment vs. burnup storage criteria are covered in section VII.2. Proposed technical specifications governing this and all other requirements for unrestricted region 2 storage are included in section VIII.1. Assemblies qualifying for unrestricted region 2 storage will be referred to as fuel category 2A throughout this submittal.

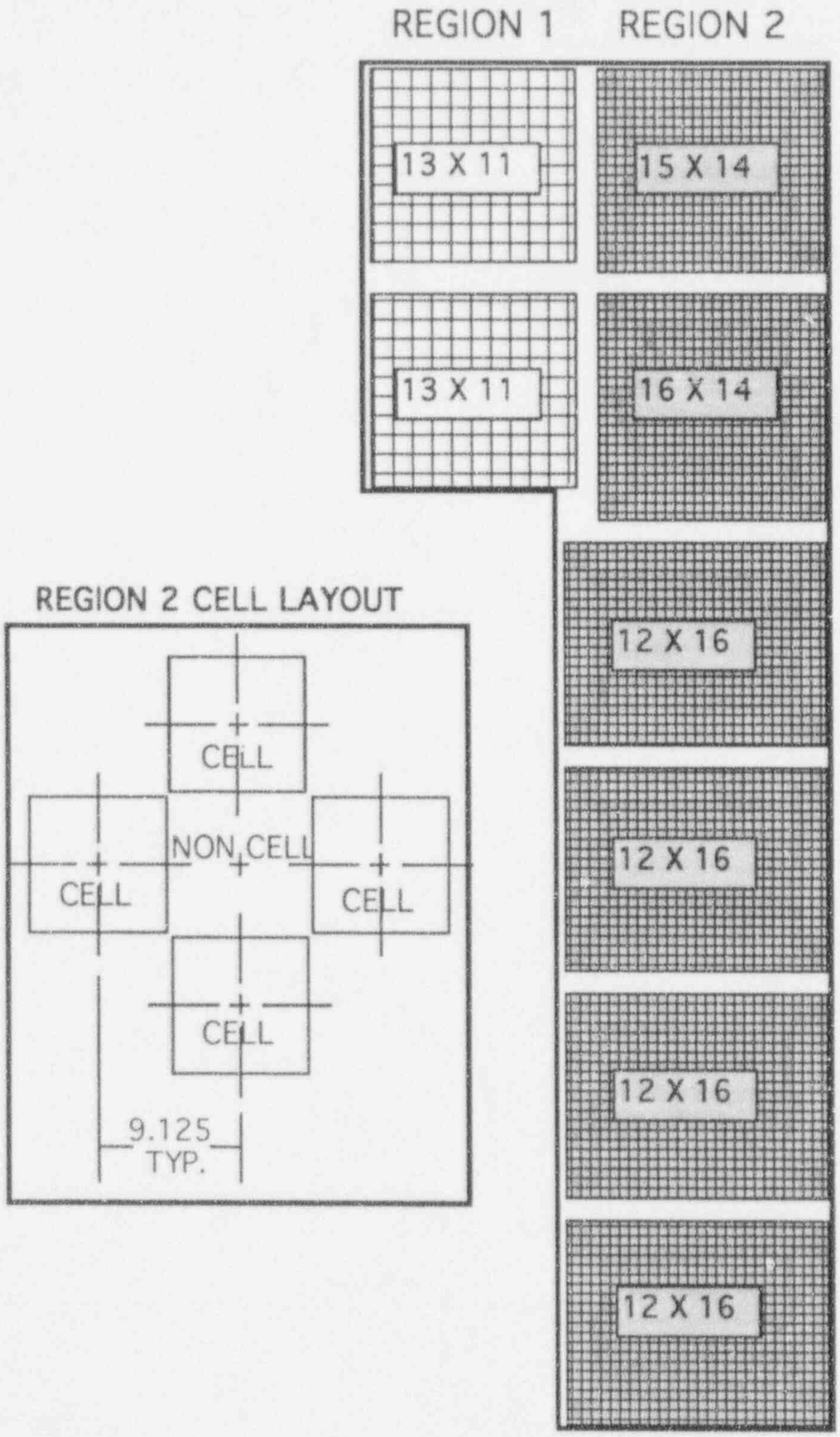


Figure 5-3

McGuire Fuel Pool Layout with Region 2 Detail

Restricted Storage

Under the current technical specifications, fuel assemblies which have been sufficiently depleted are stored in the region 2 area of the fuel pool without restriction. Assemblies which do not qualify for unrestricted storage due to excessive discharge reactivity must be placed in a 50% checkerboard configuration. Vacant spaces adjacent to these assemblies are fitted with cell blocking devices to prevent inadvertent assembly insertion. Currently, the two MNS pools have about 100 storage cells that are unusable due to these restrictions.

Based on analysis discussed in section VI.6, this document proposes a revised set of guidelines for region 2 which would be used to determine the need for restricted storage of fuel having initial enrichments up to 4.75weight% (nominal). The analysis also demonstrates that sufficiently depleted "filler" fuel assemblies can be used in place of the empty cells currently required to maintain sub-criticality within the restricted loading pattern. This approach maximizes current and future storage cell utilization. Assemblies requiring restricted region 2 storage will be referred to as fuel category 2B throughout this submittal. The proposed loading pattern is illustrated in Figure 5-4 below:

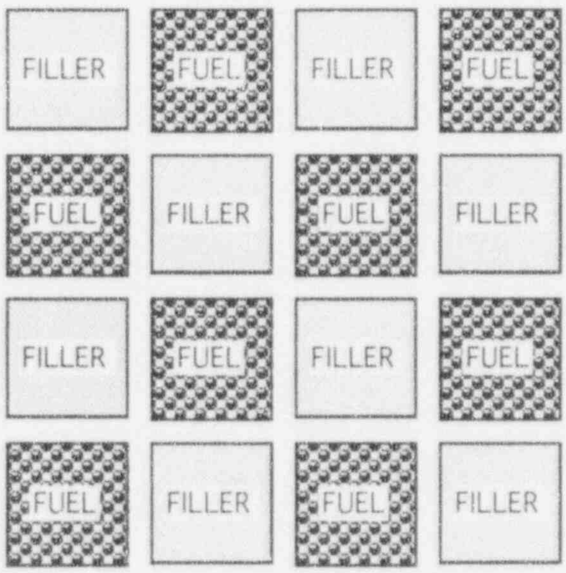


Figure 5-4
Region 2 Restricted Storage Loading Pattern

The proposed guidelines for selecting the required filler assemblies for the restricted loading pattern in region 2, are very similar to those proposed for filler selection in region 1. As discussed in section VI.6, the reactivity level (burnup curve) which best envelopes all of the current spent fuel inventory and projected future spent fuel discharges is used to determine a corresponding minimum reactivity requirement for the region 2 filler assemblies. This reactivity value is then translated into specific burnup vs. enrichment requirements which become the selection criteria for the filler assemblies. Criteria calculated for region 2 filler assemblies are provided in section VII.2. Assemblies qualified and selected for use as region 2 fillers will be referred to as fuel category $2B_f$ throughout this submittal.

Section VII.2 shows that the restricted loading pattern discussed on the previous page is critically safe for equivalent enrichments below about $1.75_{weight\%}$. Recognizing the potential for discharging fuel at reactivity levels in excess of this limit, the existing provision to allow 50% storage with blocked empty cells will still be retained to accommodate such assemblies. Assemblies requiring this loading restriction will be referred to as fuel category 2C throughout this submittal. While assemblies falling into this category are not anticipated, analysis has been performed to show this configuration to be safe up to the proposed maximum nominal initial fuel enrichment of $4.75_{weight\%}$.

Proposed technical specifications governing the restricted storage and filler assembly selection criteria and the requirements for storage of fuel category 2C are provided in section VIII.1. Existing technical specification #3.9.12b.2 which allows for direct analysis as an alternative method for determining storage pattern requirements will be retained for use in any region 2 or region 1 situation.

V.5 Region Interface Restrictions

Once the unrestricted loading criteria and restricted loading pattern requirements were established, a criticality assessment at the various loading pattern interfaces was performed. The methodology used and results of this assessment are summarized in sections VI.7 and VII.3 respectively. A more detailed discussion is included as Appendix A. These results were then used to determine the need for loading pattern restrictions at these interfaces. Specific interfaces analyzed for such restrictions were as follows:

Region 1 Unrestricted / Region 1 Restricted

Region 2 Unrestricted / Region 2 Restricted $_{(FILLER)}$

Region 2 Unrestricted / Region 2 Restricted $_{(WATER)}$

Region 2 Restricted $_{(FILLER)}$ **/ Region 2 Restricted** $_{(WATER)}$

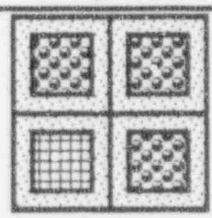
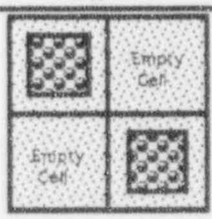
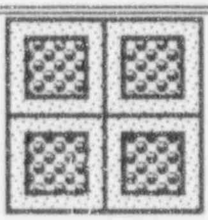
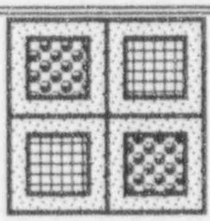
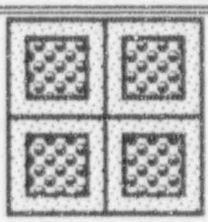
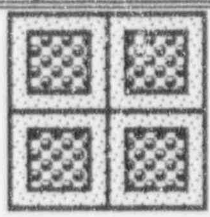
The region 1 / region 2 interface was not specifically analyzed due to a sufficient spacing between the regions to effectively isolate them from each other. Specific interface restrictions determined as necessary to maintain criticality safety at these interfaces are summarized in section VII.3. Proposed technical specifications governing these restrictions are included in section VIII.1.

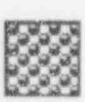
V.6 Summary

This licensing document represents a request for amendments to the McGuire technical specifications related to fuel storage under several anticipated conditions/scenarios. Figure 5-5 below illustrates in summary form the various storage configurations called for in the proposed technical specification amendments.

All current and proposed new and spent fuel storage requirements and restrictions are summarized in table 5-1 on the following page along with a specific reference to the applicable current or proposed technical specifications. Details of the requested technical specification changes are provided in section VIII.1.

Figure 5-5
Proposed Allowable Storage Configurations

Fresh Fuel Equivalent Enrichment	McGuire Region 1	McGuire Region 2
4.19- 4.75 (region 1) **1.76 - 4.75 (region2)** **Equivalent Weight %** (Low reactivity 'filler' assemblies must be less than 2.83 equivalent weight %)	 100% Loading Pattern Using 25% "Fillers"	 50% Checkerboard Loading Pattern
1.55 - 4.19 (region 1) **1.55 - 1.76 (region 2)** **Equivalent Weight %** (Low reactivity 'filler' assemblies must be less than 0.86 equivalent weight %)	 100% Loading Pattern	 100% Loading Pattern Using 50% "Fillers"
Less Than 1.55 **Equivalent Weight %**	 100% Loading Pattern	 100% Loading Pattern

 = Qualified Fuel Assembly

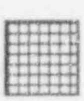
 = Qualified Filler Assembly

Table 5-1

Current and Proposed
MNS Fuel Storage Limits and Restrictions

New Fuel Storage Vault

Fuel Category	Fuel Condition	Current Limits/Requirements	Current Load Pattern	Current Reference	Proposed Limits/Requirements	Proposed Load Pattern	Proposed Reference
NF	New Fuel	Max. Init. Enr. 4.0%	100%	FSAR 9.1.1.3.2-5	Max. Init. Enr. 4.75%	100%	FSAR 9.1.1.3.2-5

Spent Fuel Pool - Region 1 Area

Fuel Category	Fuel Condition	Current Limits/Requirements	Current Load Pattern	Current Reference	Proposed Limits/Requirements	Proposed Load Pattern	Proposed Reference
1A	New Fuel	Max. Init. Enr. 4.0%	100%	FSAR 9.1.1.3.2-5	Max. Init. Enr. 4.19%	100%	New T. S. 3.9.13a.1
1B	New Fuel (Restricted) Does Not Meet 1A Limits	Not Applicable	Not Applicable	Not Applicable	Max. Init. Enr. 4.75%	75% With Filler Assemblies	FSAR 9.1.1.3.2-5 T.S. 3.9.13a.2
1A	Irradiated Fuel	Max. Init. Enr. 4.0%	100%	FSAR 9.1.1.3.2-5	Max. Init. Enr. 4.19% or Qualifying Burnup* "A"	100%	New T. S. 3.9.13a.1
1B	Irradiated Fuel (Restricted) Does Not Meet 1A Limits	Not Applicable	Not Applicable	Not Applicable	Max. Init. Enr. 4.75%	75% With Filler Assemblies or Empty Cells	FSAR 9.1.1.3.2-5 New T.S. 3.9.13a.2
1Bf	Region 1 Filler Assemblies	Not Applicable	Not Applicable	Not Applicable	Qualifying Burnup Curve B*	25% as Fillers	New T.S. 3.9.13a.2

Spent Fuel Pool - Region 2 Area

Fuel Category	Fuel Condition	Current Limits/Requirements	Current Load Pattern	Current Reference	Proposed Limits/Requirements	Proposed Load Pattern	Proposed Reference
2X	Irradiated Fuel Less Than 16 Days Cooled	Prohibited From Region 2	N/A	T. S. # 3.9.12. b	Prohibited From Region 2	N/A	New T. S. 3.9.13b
2A	Irradiated Fuel	Qualifying Burnup Curve or Direct Analysis	100%	T. S. # 3.9.12 b.1 and b.2	Qualifying Burnup Curve D* or Direct Analysis	100%	New T. S. 3.9.13b.1
2B	Irradiated Fuel (Restricted) Does Not Meet Category 2A Limits	Max. Init. Enr. 4.0%	50% Checkerboard	T. S. # 3.9.12 b.3	Qualifying Burnup Curve C* or Direct Analysis	50% Checkerboard With Filler Assemblies or Empty Cells	FSAR 9.1.1.3.2-5 New T.S. 3.9.13b.2
2C	Irradiated Fuel (Restricted) Does Not Meet Category 2B Limits	Not Applicable	Not Applicable	Not Applicable	Max. Init. Enr. 4.75%	50% Checkerboard	New T. S. 3.9.13b.3
2Bf	Region 2 Filler Assemblies	Not Applicable	Not Applicable	Not Applicable	Qualifying Burnup Curve E*	50% Checkerboard as Fillers	New T. S. 3.9.13b.2

* Qualifying Burnup Curve Legend

Curve A: Proposed Region 1 Nominal Curve - See Figure 7-1 & T. S. Table 3.9-1
Curve B: Proposed Region 1 Filler Curve - See Figure 7-1 & T. S. Table 3.9-2
Curve C: Proposed Lower Bound Region 2 Curve - See Figure 7-1 & T. S. Table 3.9-4
Curve D: Revised Region 2 Nominal Curve - See Figure 7-1 & T. S. Table 3.9-3
Curve E: Proposed Region 2 Filler Curve - See Figure 7-1 & T. S. Table 3.9-5

VI METHODOLOGY OVERVIEW

VI.1 General Purpose

This section provides an overview of the analytical methods and associated assumptions used to justify the proposed amendments to the McGuire Nuclear Station technical specifications and related modifications to the FSAR. Since the proposed changes relate only to variations in allowable fuel enrichments and pool storage configurations, criticality safety and thermal loading increase due to the anticipated higher discharge burnups are the only parameters that must be reviewed and analyzed relative to previously approved requirements. Review or modification of currently applicable seismic, structural, radiological, or environmental analyses is not considered necessary as a result of these proposed changes. Previously approved or appropriately benchmarked and described methodologies for performing the necessary criticality analyses are employed as part of this submittal to demonstrate sufficient criticality safety margins.

VI.2 Applicable Codes, Standards, and Regulations

The following listing represents those codes, standards, and regulations which are considered to be applicable to criticality safety as it relates to new and irradiated fuel storage. These were used as general guidelines in performing the necessary analyses.

- 10 CFR Part 50, General Design Criterion #62 - Prevention of Criticality in Fuel Storage and Handling
- NUREG - 0800, USNRC Standard Review Plan, Sections 9.1.1 & 9.1.2
- ANSI/ANS - 57.2 - 1983
- NRC Reg Guide 1.13 - Dec. 1975, Spent Fuel Storage Facility Design Basis
- ANSI/ANS - 57.3 - 1983, Design Requirements for New LWR Fuel Storage
- NRC Grimes Letter Revision 1 1/18/79
- ANS 51.1 - 1983, Nuclear Safety Criteria for the Design of PWR Plants
- ANSI/ANS-8.17-1984, Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors
- ANSI -N16.1-1975, "Operations with Fissionable Materials Outside Reactors"

VI.3 Design Bases and General Assumptions

Consistent with previous license applications and amendments and in compliance with the requirements of the above regulations and guides, the criticality analyses performed to support the proposed FSAR and Technical Specification changes are based on the requirement that there is a 95% probability at a 95% confidence level that the effective multiplication factor (Keff) of the fuel assembly array will be less than 0.95 (0.98 for new fuel vault under optimum moderation conditions). The calculated Keff value must also include all appropriate biases and tolerances (mechanical, method, etc).

As an additional safety margin to those included in the design bases above, several conservative assumptions related to the physical conditions, procedural controls, and neutron behavior are incorporated into the analyses. These ensure that the actual degree of subcriticality provided by the resulting safety limits will always be less than the analyzed value. The generally applicable of these assumptions are listed below:

- All pool storage configurations are assumed to be flooded with pure, unborated water at the temperature within the design limits of the pool which yields the largest reactivity.
- Reasonable penalties for axial and width shrinkage of Boraflex are assigned,
- Each storage configuration analyzed is assumed to be a 2 dimensional infinite array with no axial or radial leakage,
- Fuel assemblies are assumed to be of the Mark BW 17 x 17 design which has been shown to be the most reactive of the current and planned inventories,
- No credit is taken for burnable poisons, control rods, or other fuel assembly control components,
- All fuel pool rack analyses have incorporated a bias which has been developed to account for the B_4C particle self shielding that occurs in the Boraflex neutron poison material.

The above assumption concerning the 2 dimensional infinite array is consistent with the current analysis for the McGuire spent fuel storage racks performed by the manufacturer. The vendor studied the differences between a detailed 3-D model which included the effects of axial burnup, and an infinite 2-D model which did not. The conclusion reached by the vendor was that the reactivity differences were relatively small and that the infinite 2-D model bounded the results of the 3-D model with axial burnup effects for the typical range of minimum burnup requirements. .

Additional assumptions specifically applicable to the new fuel storage vaults are as follows:

- Water density is varied to determine optimum flooding condition
- No supplemental neutron poisons are assumed to be present.
- All assemblies are assumed to be un-irradiated with nominal enrichment values of 4.75weight% U-235 including tolerances.

VI.4 Computer Code / Methodology Description

The SCALE system of computer codes was used to perform new fuel vault reactivity calculations and to model the boundary conditions that will exist at the various fuel storage region interfaces. This methodology utilizes three dimensional Monte Carlo theory and is particularly applicable to the widely-spaced fresh fuel lattices which are typical of new fuel storage vaults. Specifically, this analysis method used the CSAS25 sequence contained in Criticality Analysis Sequence No. 4 (CSAS4). CSAS4 is a control module contained in the SCALE -3 system of codes. The CSAS25 sequence utilizes two cross section processing codes (NITAWL and BONAMI) and a 3-D Monte Carlo code (KENO Va) for calculating the effective multiplication factor for the system. The 123 Group GMTH cross section library was used exclusively for this analysis.

The SCALE-3 System of Codes is certified for use and incorporated into the QA-certified library on Duke mainframe node PRDB. CSAS4 and the 123 Group GMTH library have been further benchmarked for criticality analysis via comparison with critical experiments to determine the applicable biases and uncertainties.

The burnup credit approach to fuel rack criticality analysis requires calculation and comparison of reactivity values over a range of burnup and initial enrichment conditions. In order to accurately model characteristics of irradiated fuel which impact reactivity, a criticality analysis method capable of evaluating arrays of these irradiated assemblies is needed. In this license submittal, the advanced nodal method combining CASMO-3/TABLES-3/SIMULATE-3 is used for this purpose. CASMO-3 is an integral transport theory code, SIMULATE-3 is a nodal diffusion theory code, and TABLES-3 is a linking code which reformats CASMO-3 data for use in SIMULATE-3. This methodology permits direct coupling of in-core depletion calculations and resulting fuel isotopics with out-of-core storage array criticality analysis. While a CASMO-3/SIMULATE-3 methodology has been approved for use in nuclear design analysis (DPC-NE-1004A, November 1992), this submital extends this methodology to criticality analysis of the spent fuel pools. Similar application of this methodology to spent fuel pool analysis has been previously approved by NRC. A detailed description of the bench marking and analysis of Duke Power's application of this burnup credit methodology is provided in Appendix B. This methodology - if approved - will be utilized for additional future burnup credit/criticality analysis in support of further licensing activities.

VI.5 Fuel Storage Vault Methodology

The new fuel vaults at the McGuire Nuclear Station are designed exclusively for temporary storage of fresh unirradiated fuel. The ANSI/ANS - 57.3 Design Standard simply requires that Keff be maintained at less than or equal to 0.95 under fully flooded conditions and less than or equal to 0.98 assuming optimal moderation. Analysis used to determine Keff in these storage racks must therefore assume maximum allowable fuel enrichments. Criticality control relies strictly on the wide spacing between individual storage locations and a specified upper limit for as-built fuel assembly enrichment. This upper limit is specified in the McGuire FSAR Section 9.1.1.3.2. The absence of other factors such as soluble boron, fixed poisons, burnup effects, and fission products makes for a relatively straightforward analysis. The normally dry condition of the fuel vaults introduces the possibility of water intrusion. Consequently, full density water flooding was conservatively modeled as a normal condition in this analysis. Other less likely events which could create low density moderator conditions (i.e. foaming, misting, etc.) dictated analysis of optimum moderator conditions as an accident condition. Vault criticality analysis is therefore performed as a function of both enrichment and moderator density.

As discussed in section VI.4, the KENO Va model was used to determine the acceptability of the proposed 4.75weight%(nominal) upper fuel enrichment limit for vault storage. The analysis assumed a 100%, cell loading pattern and, consequently, no loading pattern restrictions are needed or applicable in the new fuel storage vault. Results of this analysis are summarized in section VII.1.

VI.6 Burnup Credit Methodology

In order to justify storage of fuel at or near the proposed upper enrichment limit established for the new fuel vaults, the concept of burnup credit was utilized in both regions of the McGuire fuel pools. As discussed in section VI.4 above, the variable effects of fission product poisoning, fissile material production and utilization and other related effects are accurately modeled with the CASMO/SIMULATE/TABLES methodology. Applicable biases and uncertainties are developed and become inputs to the methodology.

The basic approach is to use reactivity equivalencing techniques to construct burnup versus enrichment curves which represent equivalent and acceptable reactivity conditions over an applicable range of burnups and initial enrichments. The first curve establishes the burnup requirements for unrestricted storage or 100% cell utilization. Assemblies which fall short of the burnup requirements will require storage restrictions. A second curve is then generated to reflect the minimum requirements for restricted storage of the more reactive fuel assemblies which do not qualify for unrestricted storage.

To maximize the utilization of the storage locations while accommodating these higher enriched assemblies, the analysis also focuses on determining a loading pattern which mixes the storage of projected unqualified assemblies with appropriately selected "filler" assemblies. Reactivity limits placed on these fillers are driven by the projected reactivity of the unqualified assemblies that will be stored with them such that the reactivity of the combined loading pattern meets the design criteria. Once the reactivity requirements of these fillers is determined, a third burnup curve which represents this reactivity level is constructed. This curve is then used for qualification of the filler assemblies.

Generation of the applicable burnup credit curves requires a two part calculation process. The first part is to create two types of reactivity versus burnup curves. The first type of curve defines the maximum reactivity for the spent fuel pool such that the appropriate design criteria are met including allowances for both calculational uncertainties and manufacturing tolerances. The second type of curve represents the reactivity versus burnup for a particular enrichment, and is generated for the range of enrichments. The intersection of the maximum design reactivity curve with the multiple enrichment curves provides data points for the second part of the process.

The second part of the process generates the burnup versus initial enrichment curves by plotting the burnup where the maximum design reactivity equals the reactivity of a particular enrichment for each enrichment. Two curves are generated which represent the qualification criteria for a particular storage configuration. Each burnup versus enrichment curve shows the minimum amount of burnup required to qualify fuel for storage in the applicable loading pattern as a function of the fuel's initial enrichment. As discussed in section V, there are two storage configurations for Region 1, normal 100%

storage of qualified fuel and 75% storage of unqualified fuel with 25% qualified filler fuel. The fresh fuel has an enrichment limit of 4.75 w/o. In Region 2 there are also two storage configurations, normal 100% storage, and 50% checkerboard storage of high reactivity restricted fuel with appropriately qualified filler filler fuel. These curves and supporting data are provided in section VII.2 while additional details of the methods used to generate these curves are covered in Appendix B.

VI.7 Region Interface Methodology

The present three region configuration in the McGuire spent fuel pools provides for physical or administratively controlled separation by a minimum of 15 cm of water between adjacent regions. The separation between region 1 and region 2 is due to a physical gap between the modules. The separation between region 2 qualified storage and the checkerboard region containing unqualified fuel is achieved by the Technical Specification (TS) requirement to maintain an empty row of cells between the two regions.

As was the case for the new fuel vault criticality analysis, the KENO Va code was used to analyze the boundary conditions that are created between the regions that share the same rack modules to assure that the storage configurations at these boundaries do not cause an increase in the nominal Keff for the individual regions. Where necessary, this analysis also determined the need for new administrative restrictions at the boundaries. In performing the analyses, the base model for all region 2 checkerboard schemes are modeled as groups of four storage locations with the more reactive assemblies being modeled in the "non-cell" locations.

Other related assumptions and more detailed discussion are contained in Appendix A. The results of the boundary condition analyses are summarized in section VII.3.

VI.8 Spent Fuel Pool Cooling Considerations

While cooling time is the more dominant variable for spent fuel heat load calculations, variations in discharge burnups can also have a significant impact especially in the the more limiting cases where full core off-loads with minimal cooling times are being analyzed. An expected and desirable result of an increase in allowable fuel enrichments for the McGuire Nuclear Station would be a corresponding increase in the discharge burnups. Consequently, the spent fuel pool cooling system was reviewed for it's ability to maintain acceptable water temperatures under the expected thermal conditions associated with the higher discharge burnups.

Current burnups in the range of 40 to 50 GWD/MTU are the basis for the current thermal analysis which demonstrates the effectiveness of the spent fuel pool cooling system. Batch average burnups in excess of this range are eventually anticipated with the approval of this amendment request. Based on these higher anticipated burnup levels, an analysis of the corresponding heat loads was performed assuming worst case and normal operating conditions. This analysis shows that despite these higher heat loads, spent fuel pool water temperatures will remain within the 140°F requirements specified in NRC reg guide 1.13 and in ANSI Standard 57.2. The results of this analysis reflecting these more limiting conditions will be reflected in FSAR modifications.

VI.9 Misloaded Fuel Considerations

As with the original safety assessment for the storage rack arrangements in the two McGuire spent fuel pools, this proposed enrichment upgrade creates the potential for fuel mis-loading accident conditions which were considered. In these cases, the excess negative reactivity provided by the soluble boron in the spent fuel pool water is sufficient to maintain the pool configuration at or below an acceptable Keff of 0.98. Accident conditions considered include the following:

1. Mis-loading of fuel in region 1:
   a. Failure to provide appropriate "filler" assemblies for fuel above 4.19% actual or equivalent enrichment.

2. Mis-loading of fuel in region 2:
   a. Failure to provide appropriate "filler" assemblies adjacent to fuel in category 2B.
   b. Failure to provide water cells adjacent to fuel in category 2C.

Analyses performed to evaluate the above misloading accident conditions were all based on misloading unirradiated, 4.75weight% fuel assemblies into the filler or empty cell locations required by the technical specifications. Results of those analyses are provided in section VII.4.

VII GENERAL RESULTS OF ANALYSES

This section provides the basic results of the various analyses performed in support of the proposed FSAR and Technical Specification changes. Additional discussion of the supporting analytical techniques can be found in Appendices A and B.

VII.1 New Fuel Vaults

The calculated worst-case K_{eff} for a fuel assembly with the maximum enrichment of 4.75weight% (nominal) U-235 is shown below.

$$k_{eff} = 0.949945$$

This value was specifically calculated for the Mark BW fuel design which has been shown to be the most reactive of the three fuel types which exist at McGuire. This value also includes geometrical and material uncertainties and biases at a 95 percent probability and a 95 percent confidence level as required to demonstrate criticality safety. The uncertainties considered include:

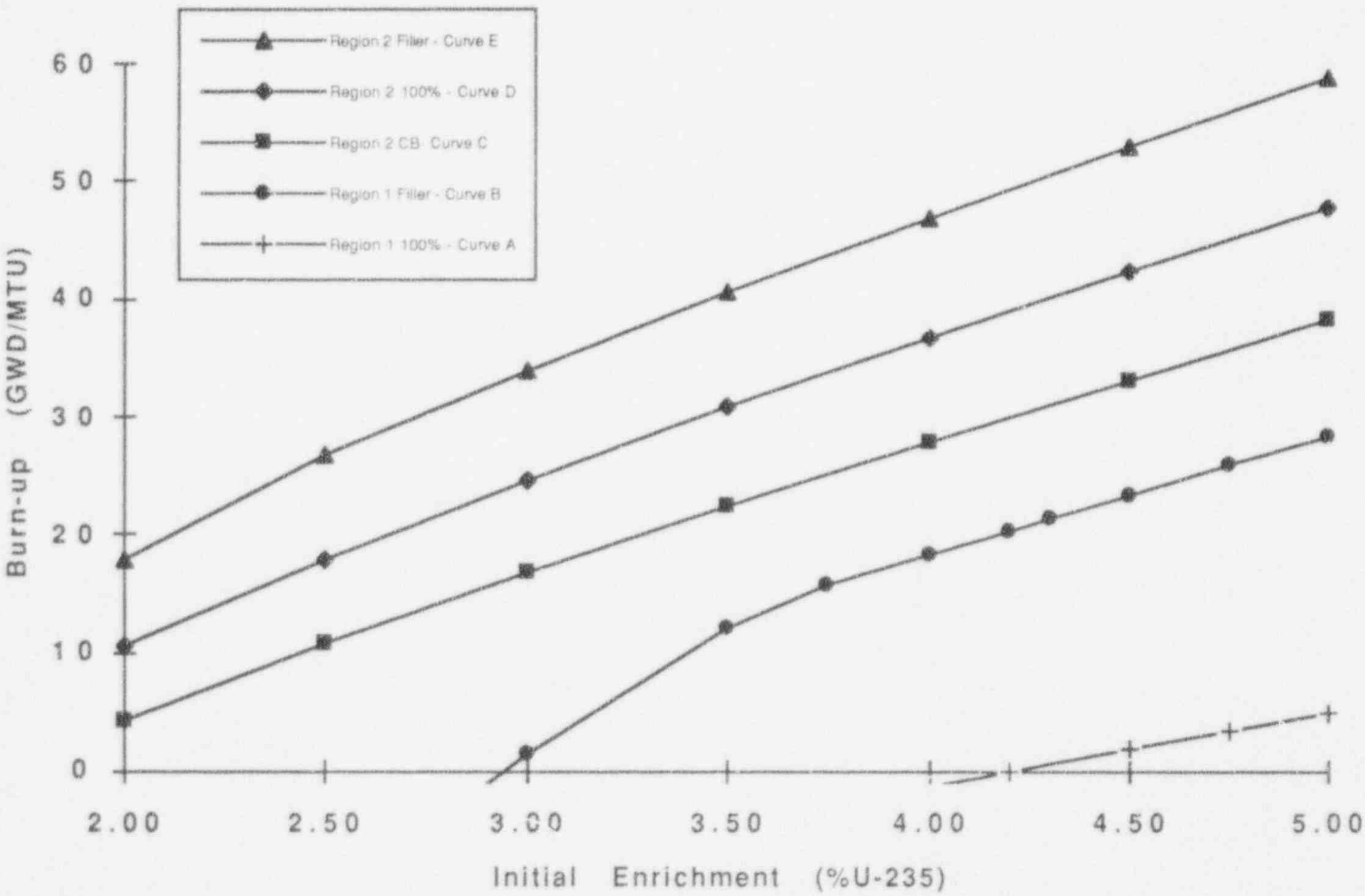
Embedded concrete tolerances
Fuel Cage tolerances

As specified in ANSI/ANS 57.3, the maximum k_{eff} value in a LWR new fuel storage vault shall be less than or equalto 0.98 under optimum moderator conditions and less than or equal to 0.95 under fully flooded conditions. The analytical result shown above indicates that this criteria has been met.

VII.2 Fuel Assembly Burnup Requirements

The results of the criticality analysis used to determine burnup requirements for the various fuel loading configurations in both regions of the McGuire pools are summarized by the five burnup curves shown in figure 7-1 below. Specific data points generated by the criticality analysis and used to create these 5 burnup curves are shown in Table 7-1 on the following page.

Figure 7-1
<u>McGuire Fuel Pool Storage Curves</u>



Curve A	Minimum requirements for unrestricted (100%) fuel storage in region 1 (Category 1A). Region 1 assemblies not meeting curve A requirements must be stored in a 75% load pattern in region 1 with qualified filler assemblies (Fuel Category 1B).
Curve B	Minimum requirements for region 1 filler assemblies (Category $1B_f$).
Curve C	Minimum requirements for 50% loading pattern in region 2 with qualified assys (Category 2B). Region 2 assemblies not meeting Curve C requirements must be stored in a 50% loading pattern with blocked empty cells (Category 2C).
Curve D	Minimum requirements for unrestricted storage in region 2 (Category 2A).
Curve E	Minimum requirements for region 2 filler assemblies (Category $2B_f$).

Table 7-1
McGuire Fuel Pool
Storage Qualification Requirements

Region 1	Enrich -ment	3.00	3.50	4.00	4.50	4.75
100 %	Burnup (GWD/MTU)	-	-	-1.29	1.92	3.40
Filler	Burnup (GWD/MTU)	1.57	13.30	18.32	23.36	25.84

Region 2	Enrich -ment	2.00	2.50	3.00	3.50	4.00	4.50	5.00
100%	Burnup (GWD/MTU)	10.54	17.96	24.64	30.86	36.75	42.38	47.81
Checker board	Burnup (GWD/MTU)	4.22	10.75	16.80	22.41	27.92	33.14	38.16
Filler	Burnup (GWD/MTU)	18.03	26.71	33.79	40.56	46.83	52.86	58.69

VII.3 Region Interface Restrictions

Region 1

As discussed earlier in section V and summarized in table 5-1, the region 1 area of the fuel pools will be made up of two sub regions (1A and 1B) to accommodate fuel above and below the 4.19 weight% equivalent enrichment value. The boundary conditions between these regions were analyzed in an attempt to determine the worst geometry configuration for neutronic coupling between the cells of differing enrichments. In this process it was discovered that to assure that the boundary between regions will have no effect on the k_{eff}, the border between regions must be a row of alternating "filler" assemblies and the "unqualified" assemblies. A full row of unqualified assemblies serving as this boundary would **not** be acceptable.

The distance from region 1 to region 2 is sufficient to isolate the two regions. Consequently no loading restrictions are necessary at the interface between the two regions.

Region 2

The Region 2 area of the pools were re analyzed to accommodate 3 separate sub regions as summarized in table 5-1. Fuel which can be stored without restriction makes up region 2A. Fuel which must be checkerboarded 50% with "filler" assemblies defines region 2B and fuel which must be checkerboarded 50% with water cells will make up a region 2C.

The interface restrictions between region 2B and 2C and between 2A and 2C are basically the same. As opposed to the boundary between region 2A and 2B where any region could bound the other on all four sides, the calculations reveal that for the boundaries between 2B and 2C, along with region 2A and 2C, only two opposite sides of one region can bound the other. The other two sides must either bound the fuel pool wall or an empty row of cells.

The distance from region 2 to region 1 is sufficient to isolate the two regions. Consequently no loading restrictions are necessary at the interface between the two regions.

All proposed boundary restrictions as discussed above are summarized below:

Region Interface Restrictions	
Region 1A and 1B	Row of region 1B bounding region 1A must be a row of alternating region 1B fuel types and region1B filler locations.
Region 2A and 2B	No Interface Restrictions
Region 2A or 2B and 2C	At least 2 opposite sides of region 2C shall be bounded by either a row of empty water cells or the fuel pool wall. The remaining side(s) may be either region 2A or region 2B or both.
Region 1 and 2	No Interface Restrictions

VII.4 Fuel Misloading Accident Analysis

The following table summarizes the results of specific analyses performed to verify that sufficient margin is provided by the soluble boron to maintain the pool configuration at or below Keff of 0.98 following various postulated fuel misloading accidents.

<u>Summary of Misloading Accident Analysis</u>

Misloading Accident Event Description	K_{eff} Maintained at or Below 0.98 with 2000ppm Soluble Boron
Region 1 "Filler" Location Misloaded with 4.75 weight% Fuel	Yes
Region 2 "Filler" Location Misloaded with 4.75 weight% Fuel	Yes
Region 2 Empty Cell Location Misloaded with 4.75 weight% Fuel	Yes

VIII PROPOSED TECHNICAL SPECIFICATION / FSAR MODIFICATIONS

This section contains the proposed modifications to the MNS Technical Specifications being requested with this submittal as well as a discussion of the resulting necessary changes that will be made in the McGuire Nuclear Station FSAR upon approval of this amendment request or in the very first annual update which follows NRC's approval.

VIII.1 Technical Specification Changes

The following changes are those necessary to raise the maximum fuel enrichment allowed for use at the McGuire Station to 4.75weight%. Specific spent fuel pool loading restrictions necessary to maintain acceptable criticality safety margins for all new and irradiated fuel with initial enrichments at or below this new value are ensured by these changes. Administrative controls necessary to ensure compliance with these revised technical specifications are discussed in section IX.

The new fuel storage vaults were specifically analyzed and determined to provide acceptable criticality safety margins for fuel enrichments at or below the new 4.75 weight% limit. Consequently no loading pattern storage restrictions or related technical specifications are necessary for the new fuel storage vaults.

Current Requirements:

Technical Specification Reference: 3/4.9 Refueling Operations

UNIT 1 ONLY

Section 3/4.9 Refueling Operations

LIMITING CONDITION FOR OPERATION

3.9.12 Fuel is to be stored in the spent fuel storage pool with

a. The boron concentration in the spent fuel pool maintained at greater than or equal to 2000 ppm; and

b. Storage in Region 2 restricted to irradiated fuel which has decayed at least 16 days and one of the following:

   1) Fuel which has been qualified in accordance with Table 3.9-1; or

   2) Fuel which has been qualified by means of an analysis using NRC approved methodology to assure with a 95 percent probability at a 95 percent confidence level that k_{eff} is no greater than 0.95 including all uncertainties; or

   3) Unqualified fuel stored in a checkerboard configuration. In the event checkerboard storage is used, one row between normal storage locations and checkerboard storage locations will be vacant.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined a fuel assembly has been placed in the incorrect Region until such time as the correct storage location is determined. Move the assembly to its correct location before resumption of any other fuel movement.

b. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined the pool boron concentration is less than 2000 ppm, until such time as the boron concentration is increased to 2000 ppm or greater.

c. The provisions of Specification 3.0.3 are not applicable.

Current Requirements: (Con't)

UNIT 1 ONLY

SURVEILLANCE REQUIREMENTS:

4.9.12.a Verify all fuel assemblies to be placed in Region 2 of the spent fuel pool are within the enrichment and burnup limits of Table 3.9-1 or that $k_{eff} \leq 0.95$ by checking the assemblies' design and burnup documentation or the assemblies' qualifying analysis documentation respectively.

b. Verify at least once per 31 days that the spent fuel pool boron concentration is greater than 2000 ppm.

Current Requirements: (Con't)

UNIT 2 ONLY

Section 3/4.9 Refueling Operations

LIMITING CONDITION FOR OPERATION

3.9.12 Fuel is to be stored in the spent fuel storage pool with

a. The boron concentration in the spent fuel pool maintained at greater than or equal to 2175 pprn; and

b. Storage in Region 2 restricted to irradiated fuel which has decayed at least 16 days and one of the following:

1) Fuel which has been qualified in accordance with Table 3.9-1; or

2) Fuel which has been qualified by means of an analysis using NRC approved methodology to assure with a 95 percent probability at a 95 percent confidence level that k_{eff} is no greater than 0.95 including all uncertainties; or

3) Unqualified fuel stored in a checkerboard configuration. In the event checkerboard storage is used, one row between normal storage locations and checkerboard storage locations will be vacant.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined a fuel assembly has been placed in the incorrect Region until such time as the correct storage location is determined. Move the assembly to its correct location before resumption of any other fuel movement.

b. Suspend all actions involving the movement of fuel in the spent fuel pool if it is determined the pool boron concentration is less than 2175 ppm, until such time as the boron concentration is increased to 2175 ppm or greater.

c. The provisions of Specification 3.0.3 are not applicable.

Current Requirements: (Con't)

UNIT 2 ONLY

SURVEILLANCE REQUIREMENTS:

4.9.12.a Verify all fuel assemblies to be placed in Region 2 of the spent fuel pool are within the enrichment and burnup limits of Table 3.9-1 or that $k_{eff} \leq 0.95$ by checking the assemblies' design and burnup documentation or the assemblies' qualifying analysis documentation respectively.

b. Verify at least once per 31 days that the spent fuel pool boron concentration is greater than 2175 ppm.

Current Requirements: (Con't)

Table 3.9-1

Minimum Qualifying Burnup Versus Initial Enrichment for Region 2 Storage

Initial Enrichment w/o U-235	Assembly Burnup (GWD/MT)
1.4	0.00
1.5	2.50
1.6	5.00
1.7	6.65
1.8	8.30
1.9	9.95
2.0	11.60
2.1	13.20
2.2	14.60
2.3	16.00
2.4	17.40
2.5	18.80
2.6	20.20
2.7	21.40
2.8	22.60
2.9	23.90
3.0	25.20
3.1	26.60
3.2	27.80
3.3	28.93
3.4	30.07
3.5	31.20
3.6	32.26
3.7	33.32
3.8	34.38
3.9	35.44
4.0	36.50

Proposed Requirements:

Technical Specification Reference: 3/4.9 Refueling Operations

UNITS 1 and 2

REFUELING OPERATIONS

3/4.9.12 SPENT FUEL POOL BORON CONCENTRATION

LIMITING CONDITION FOR OPERATION

3.9.12 The boron concentration in the spent fuel pool shall be within the limit specified in the COLR.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Immediately suspend movement of fuel assemblies in the spent fuel pool and initiate action to restore the spent fuel pool boron concentration to within its limit.

b. The provisions of Specification 3.0.3 are not applicable.

SURVEILLANCE REQUIREMENTS:

4.9.12 Verify at least once per 31 days that the spent fuel pool boron concentration is within its limit.

Proposed Requirements: (Con't)

3/4.9.13 SPENT FUEL ASSEMBLY STORAGE

LIMITING CONDITION FOR OPERATION

3.9.13 Storage of new or irradiated fuel is limited to the configurations described in this specification.

a. New or irradiated fuel may be stored in Region 1 of the Spent Fuel Pool in accordance with these limits:

1) Unrestricted storage of fuel meeting the criteria of Table 3.9-1; or

2) Restricted storage in accordance with Figure 3.9-1, of fuel which does not meet the criteria of Table 3.9-1; or

3) Another configuration determined to be acceptable by means of an analysis to ensure that k_{eff} is less than or equal to 0.95.

b. New or irradiated fuel which has decayed at least 16 days may be stored in Region 2 of the Spent Fuel Pool in accordance with these limits:

1) Unrestricted storage of fuel meeting the criteria of Table 3.9-3; or

2) Restricted storage in accordance with Figure 3.9-2, of fuel which meets the criteria of Table 3.9-4; or

3) Checkerboard storage in accordance with Figure 3.9-3 of fuel which does not meet the criteria of Table 3.9-4; or

4) Another configuration determined to be acceptable by means of an analysis to ensure that k_{eff} is less than or equal to 0.95.

APPLICABILITY:

During storage of fuel in the spent fuel pool.

ACTION:

a. Immediately initiate action to move the noncomplying fuel assembly to the correct location.

b The provisions of Specification 3.0.3 are not applicable.

Proposed Requirements: (Con't)

SURVEILLANCE REQUIREMENTS:

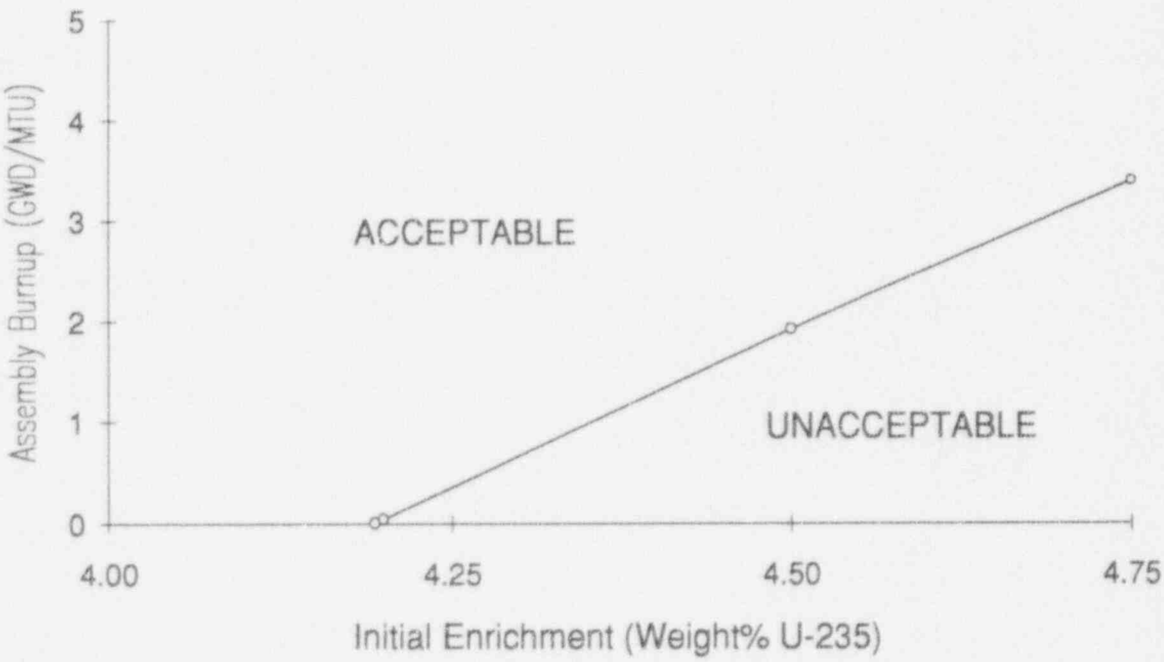
4.9.13 Prior to storing a fuel assembly in the spent fuel storage pool, verify by administrative means the initial enrichment and burnup of the fuel assembly are in accordance with Specification 3.9.13.

Proposed Requirements: (Con't)

Table 3.9-1

Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 1 Storage

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
4.19 (or less)	0
4.20	0.04
4.50	1.92
4.75	3.40

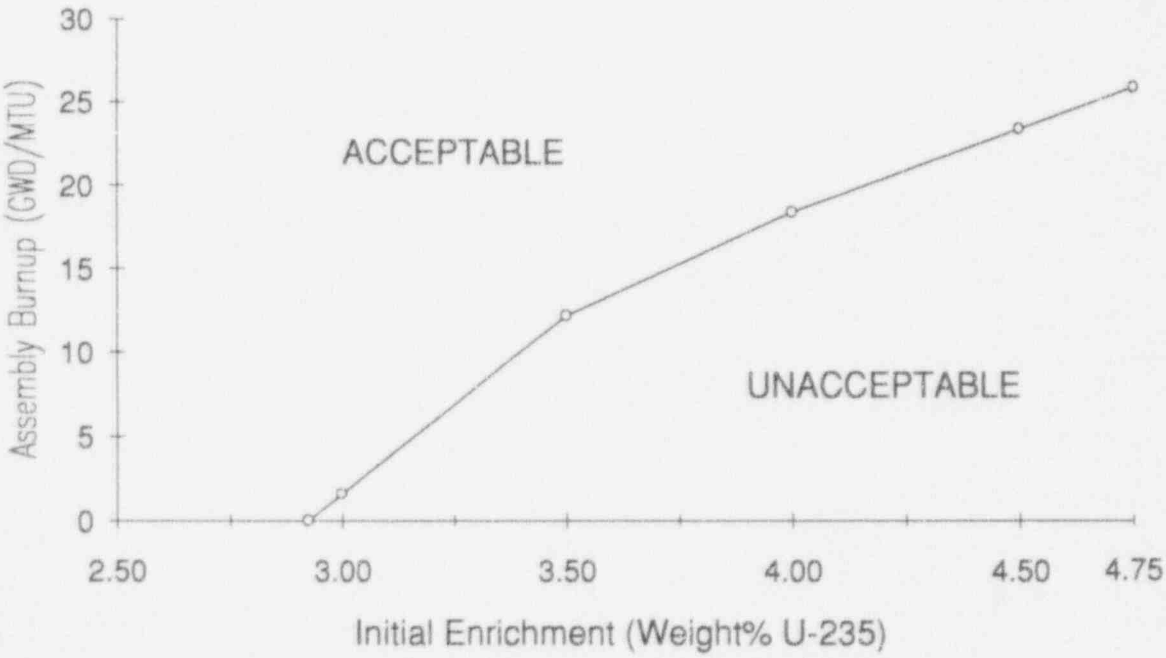


Proposed Requirements: (Con't)

Table 3.9-2

Minimum Qualifying Burnup Versus Initial Enrichment for Region 1 Filler Assemblies

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.92 (or less)	0
3.00	1.57
3.50	13.30
4.00	18.32
4.50	23.36
4.75	25.84

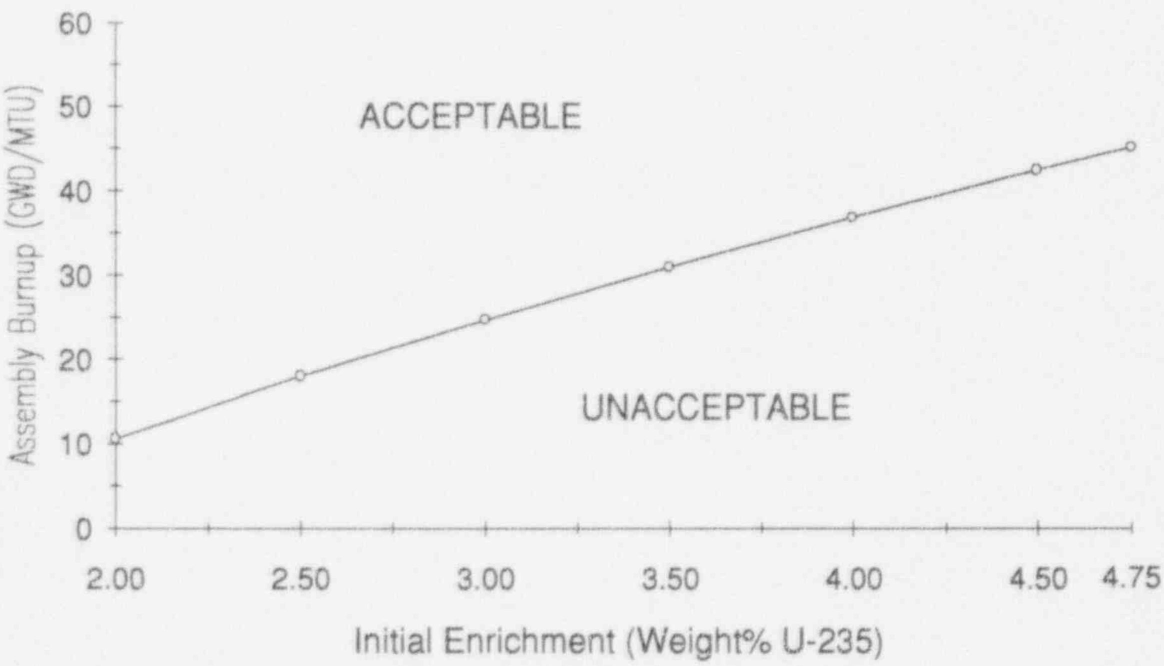


Proposed Requirements: (Con't)

Table 3.9-3

Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 2 Storage

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	10.54
2.50	17.96
3.00	24.64
3.50	30.86
4.00	36.75
4.50	42.38
4.75	45.10

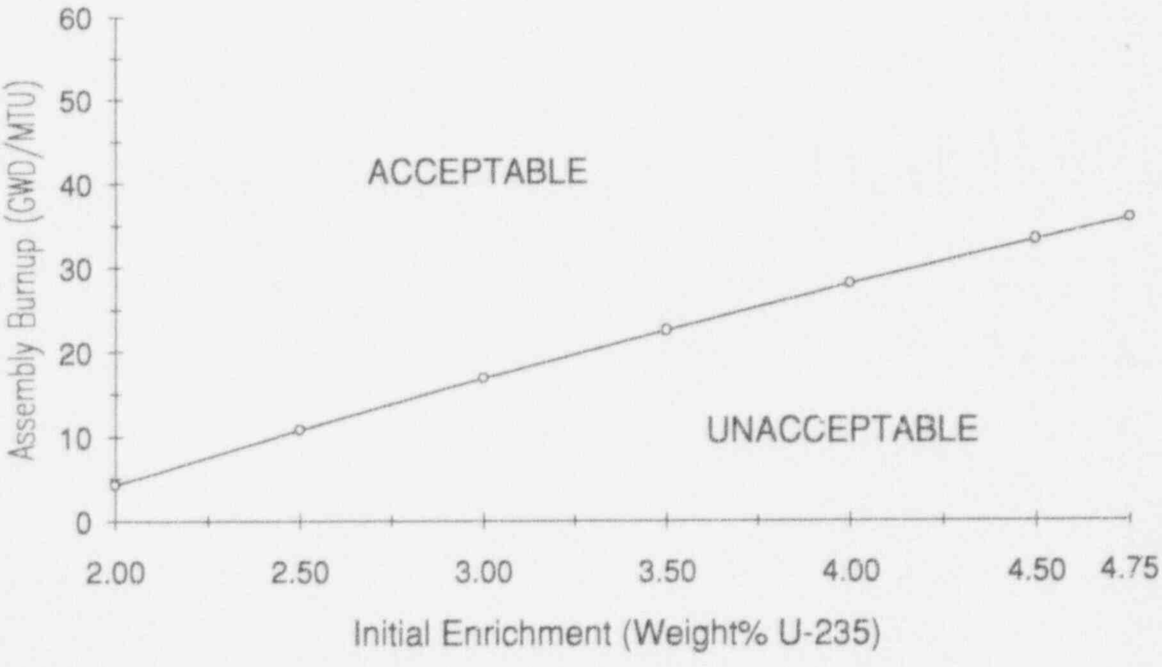


Proposed Requirements: (Con't)

Table 3.9-4

Minimum Qualifying Burnup Versus Initial Enrichment for Restricted Region 2 Storage with Fillers

Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	4.22
2.50	10.75
3.00	16.80
3.50	22.41
4.00	27.92
4.50	33.14
4.75	35.65

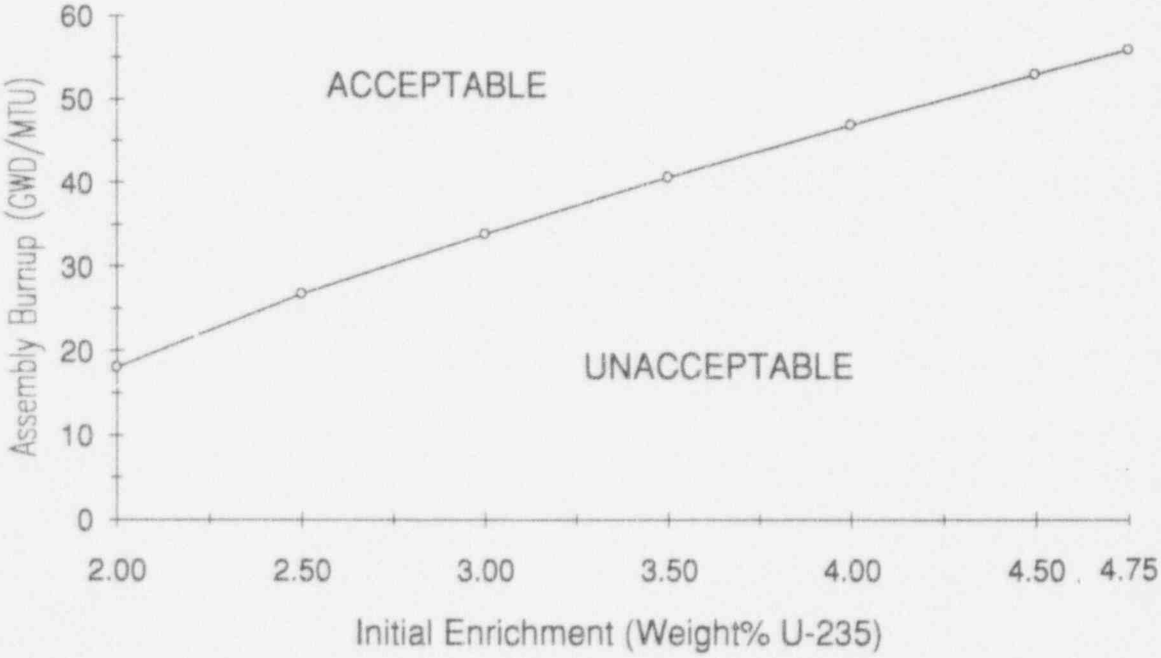


Proposed Requirements: (Con't)

Table 3.9-5

Minimum Qualifying Burnup Versus Initial Enrichment for Region 2 Filler Assemblies

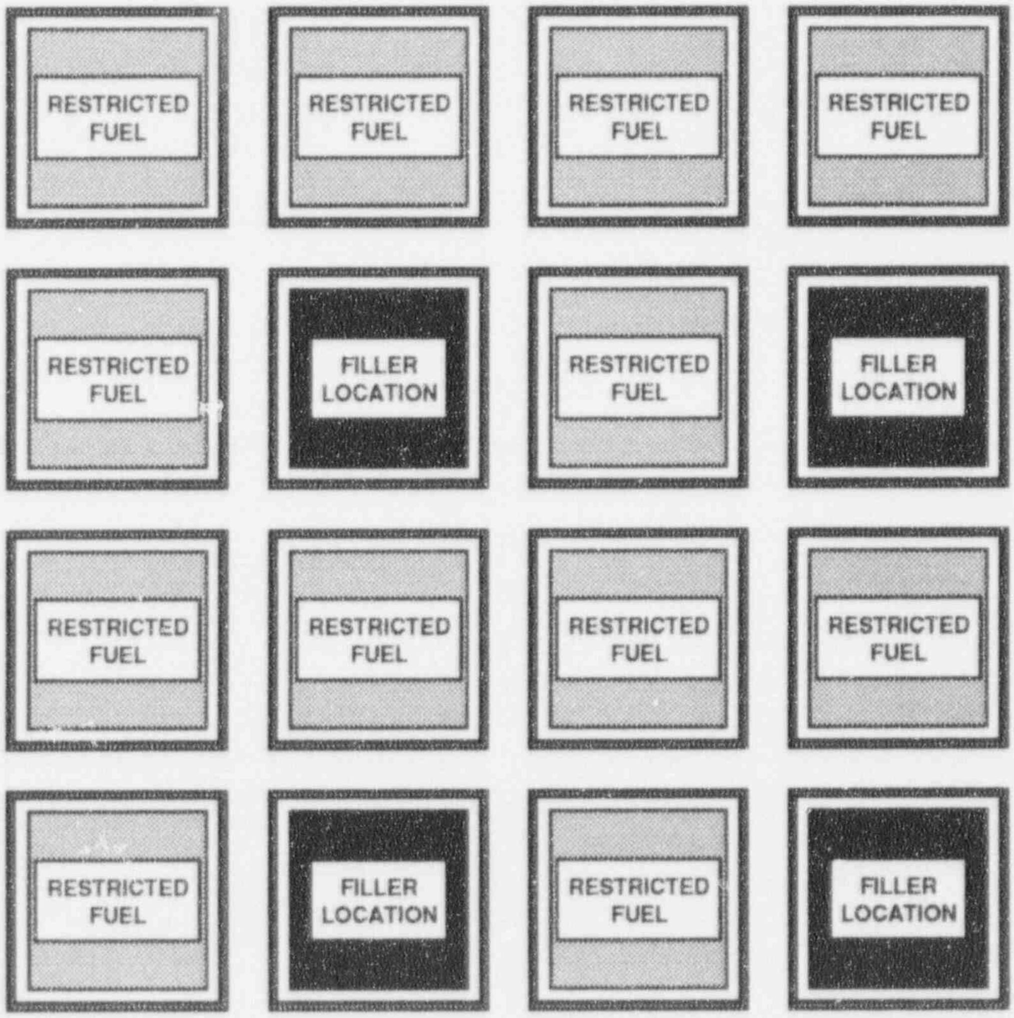
Initial Enrichment Weight% U-235	Assembly Burnup (GWD/MTU)
2.00 (or less)	18.03
2.50	26.71
3.00	33.79
3.50	40.56
4.00	46.83
4.50	52.86
4.75	55.78



Proposed Requirements: (Con't)

Figure 3.9-1

Required 3 out of 4 Loading Pattern
for Restricted Region 1 Storage



Restricted Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.9-1. (Fuel which does meet the requirements of Table 3.9-1 may be placed in restricted fuel locations as needed)

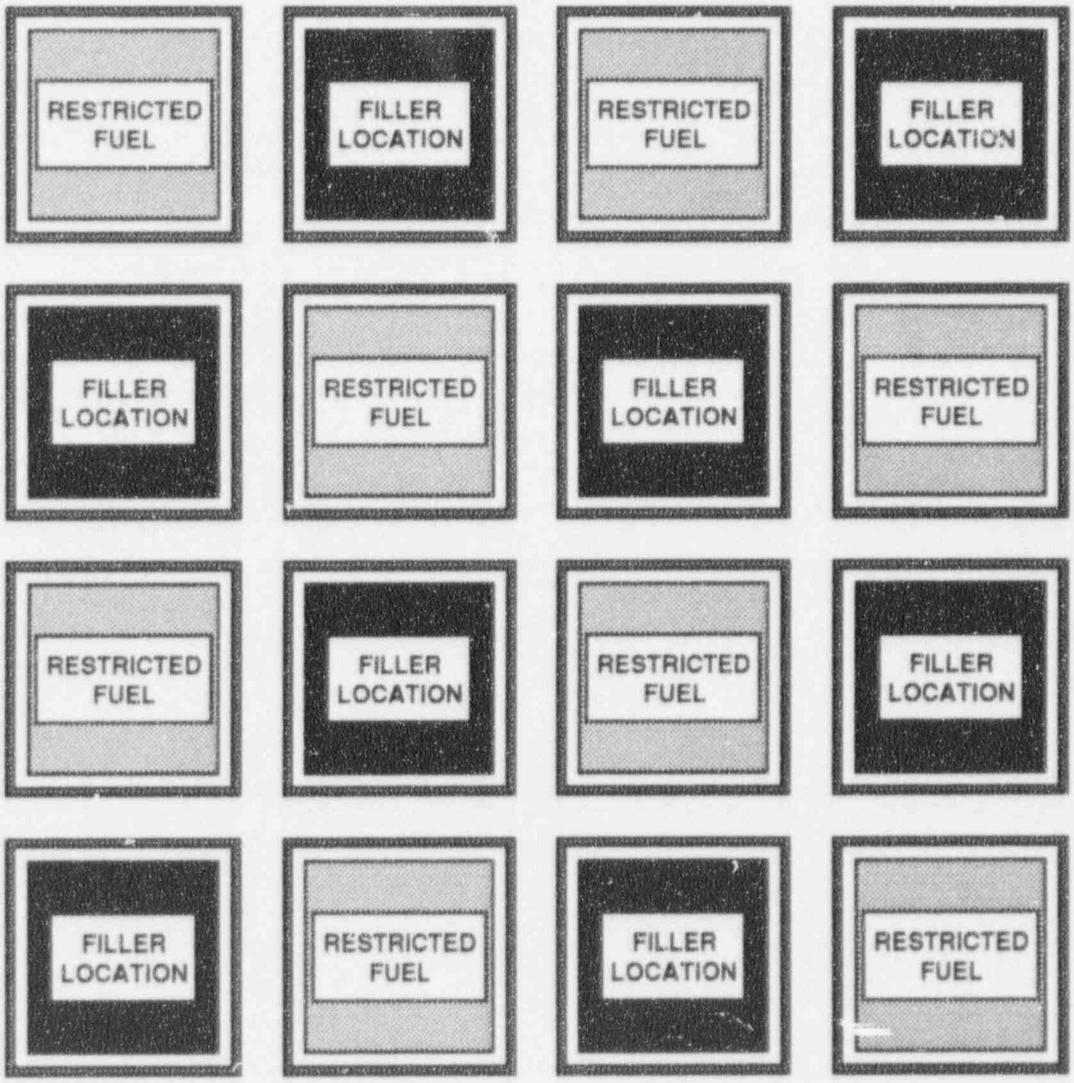
Filler Location: Either fuel which meets the minimum burnup requirements of Table 3.9-2, or an empty cell.

Boundary Condition: Any row bounded by a Region 1 Unrestricted Storage Area shall contain a combination of restricted fuel assemblies and filler locations arranged such that no restricted fuel assemblies are adjacent to each other.
Example: In the figure above, row 1 or column 1 can not be adjacent to a Region 1 Unrestricted Storage Area, but row 4 or column 4 can be.

Proposed Requirements: (Con't)

Figure 3.9-2

Required 2 out of 4 Loading Pattern
for Restricted Region 2 Storage

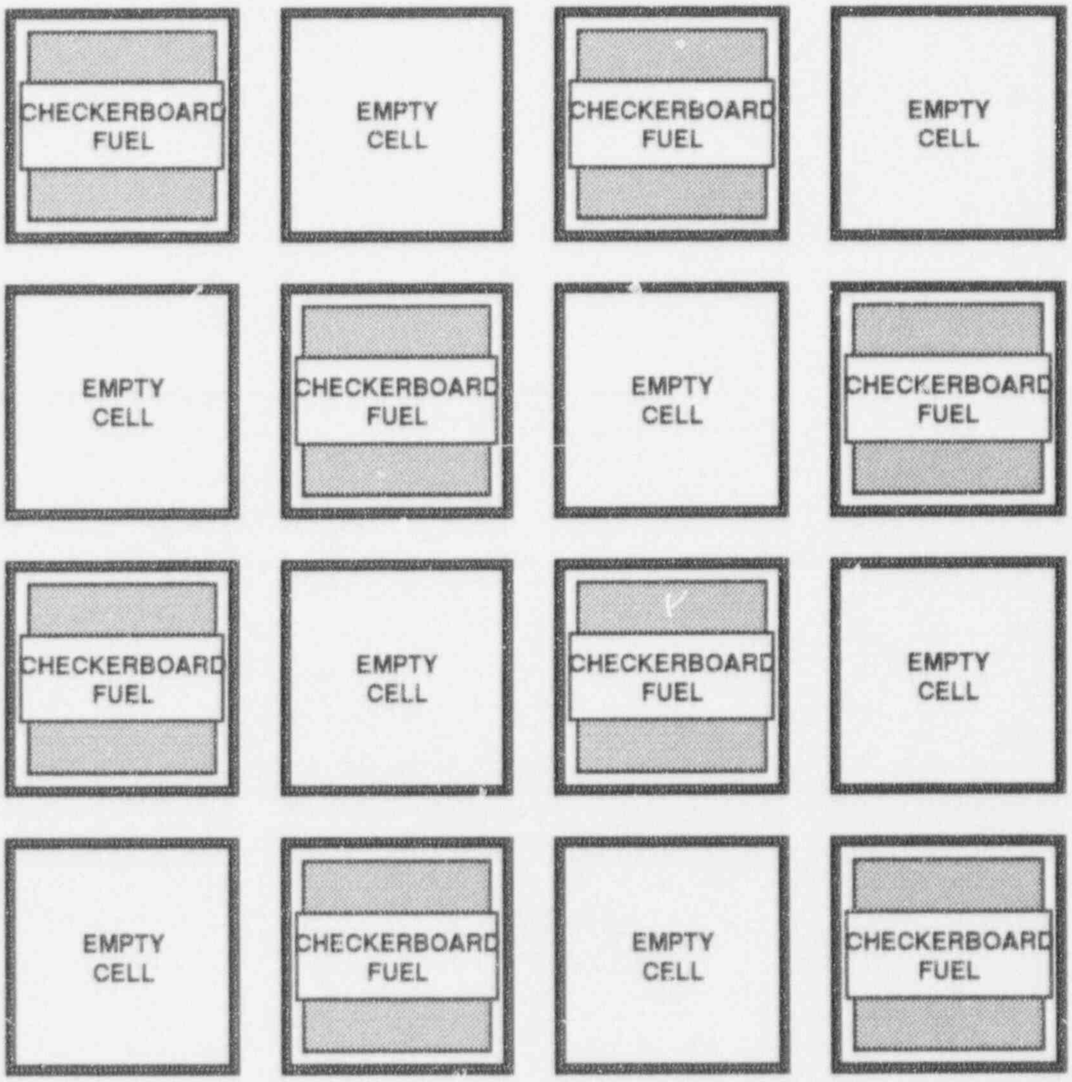


Restricted Fuel:	Fuel which meets the minimum burnup requirements of Table 3.9-4.
Filler Location:	Either fuel which meets the minimum burnup requirements of Table 3.9-5, or an empty cell.
Boundary Condition:	No restrictions on boundary assemblies.

Proposed Requirements: (Con't)

Figure 3.9-3

Required 2 out of 4 Loading Pattern for Checkerboard Region 2 Storage



Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.9-4. (Fuel which does meet the requirements of Table 3.9-4 may be placed in checkerboard fuel locations as needed)

Boundary Condition: At least two opposite sides shall be bounded by either an empty row of cells, or a spent fuel pool wall.

Current Requirements:

Technical Specification Reference: 3/4.9 Refueling Operations

UNIT 1 ONLY

BASES

3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

The requirements for fuel storage in the spent fuel pool on 3.9.12 (a) and (b) ensure that: (1) the spent fuel pool will remain subcritical during fuel storage; and (2) a uniform boron concentration is maintained in the water volume in the spent fuel pool for reactivity control. The value of 0.95 or less for Keff which includes all uncertainties at the 95/95 probability/confidence level as described in Section 9.1.2.3.1 of the FSAR is the acceptance criteria for fuel storage in the spent fuel pool. Table 3.9-1 is conservatively developed in accordance with the acceptance criteria and methodology referenced in Section 5.6 of the Technical Specifications. Storage in a checkerboard configuration in Region 2 meets all the acceptance criteria referenced in Section 5.6 of the Technical Specifications and is verified in a semi-annual basis after initial verification through administrative controls.

The Action Statement applicable to fuel storage in the spent fuel pool ensures that: (1) the spent fuel pool is protected from distortion in the fuel storage pattern that could result in a critical array during the movement of fuel; and (2) the boron concentration is maintained at 2000 ppm during all actions involving movement of fuel in the spent fuel pool.

The Surveillance Requirements applicable to fuel storage in the spent fuel pool ensure that: (1) fuel stored in Region 2 meets the enrichment and burnup limits of Table 3.9-1 or the $K_{eff} \leq 0.95$ acceptance criteria of an analysis using NRC approved methodology; and (2) the boron concentration meets the 2000 ppm limit.

UNIT 2 ONLY

BASES

3/4.9.12 FUEL STORAGE - SPENT FUEL STORAGE POOL

The requirements for fuel storage in the spent fuel pool on 3.9.12 (a) and (b) ensure that: (1) the spent fuel pool will remain subcritical during fuel storage; and (2) a uniform boron concentration is maintained in the water volume in the spent fuel pool for reactivity control. The value of 0.95 or less for Keff which includes all uncertainties at the 95/95 probability/confidence level as described in Section 9.1.2.3.1 of the FSAR is the acceptance criteria for fuel storage in the spent fuel pool. Table 3.9-1 is conservatively developed in accordance with the acceptance criteria and methodology referenced in Section 5.6 of the Technical Specifications. Storage in a checkerboard configuration in Region 2 meets all the acceptance criteria referenced in Section 5.6 of the Technical Specifications and is verified in a semi-annual basis after initial verification through administrative controls.

The Action Statement applicable to fuel storage in the spent fuel pool ensures that: (1) the spent fuel pool is protected from distortion in the fuel storage pattern that could result in a critical array during the movement of fuel; and (2) the boron concentration is maintained at 2175 ppm during all actions involving movement of fuel in the spent fuel pool.

The Surveillance Requirements applicable to fuel storage in the spent fuel pool ensure that: (1) fuel stored in Region 2 meets the enrichment and burnup limits of Table 3.9-1 or the $K_{eff} \leq 0.95$ acceptance criteria of an analysis using NRC approved methodology; and (2) the boron concentration meets the 2175 ppm limit.

Proposed Requirements:

Technical Specification Reference: 3/4.9 Refueling Operations

UNITS 1 and 2

BASES

3/4.9.12 and 3/4.9.13 SPENT FUEL POOL BORON CONCENTRATION and SPENT FUEL ASSEMBLY STORAGE

The requirements for spent fuel pool boron concentration specified in Specification 3.9.12 ensure that a minimum boron concentration is maintained in the pool. The requirements for spent fuel assembly storage specified in Specification 3.9.13 ensure that the pool remains subcritical. The water in the spent fuel storage pool normally contains soluble boron, which results in large subcriticality margins under actual operating conditions. However, the NRC guidelines based upon the accident condition in which all soluble poison is assumed to have been lost, specify that the limiting k_{eff} of 0.95 be evaluated in the absence of soluble boron. Hence the design of the spent fuel storage racks is based on the use of unborated water, which maintains each region in a subcritical condition during normal operation with the spent fuel pool fully loaded. The double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 4) allows credit for soluble boron under other abnormal or accident conditions, since only a single accident need be considered at one time. For example, the most severe accident scenario is associated with the movement of fuel from Region 1 to Region 2, and accidental misloading of a fuel assembly in Region 1 or Region 2. This could increase the reactivity of the spent fuel pool. To mitigate these postulated criticality related accidents, boron is dissolved in the pool water.

Specification 3.9.13.a.3 and 3.9.13.b.4 allow for specific criticality analysis for configurations other than those explicitly defined in Specification 3.9.13. These analyses would require using NRC approved methodology to ensure that $k_{eff} \leq 0.95$ with a 95 percent probability at a 95 percent confidence level as described in Section 9.1 of the FSAR.

In verifying the design criteria of $k_{eff} \leq 0.95$, the criticality analysis assumed the most conservative conditions, i.e. fuel of the maximum permissible reactivity for a given configuration. Since the data presented in Specification 3.9.13.a and 3.9.13.b represents the maximum reactivity requirements for acceptable storage, substitutions of less reactive components would also meet the $k_{eff} \leq 0.95$ criteria. Hence, any non-fuel component may be placed in a designated empty cell location. Likewise, an empty cell, or a non-fuel component may be substituted for any designated fuel assembly location. These, or other substitutions which will decrease the reactivity of a particular storage cell will only decrease the overall reactivity of the spent fuel storage pool.

If both restricted and unrestricted storage is used in Region 1, an additional criteria has been imposed to ensure that the boundary row between these two configurations would not locally increase the reactivity above the required limit. Likewise if checkerboard

Proposed Requirements: (Con't)

storage is used in Region 2, an additional restriction has been imposed on the boundaries of the checkerboard storage region to ensure that the reactivity would not increase above the required limit. No other restrictions on region interfaces are necessary.

For storage in Region 2 requiring loading pattern restrictions, (per Specifications 3.9.13.b.2 or 3.9.13.b.3) fuel may be stored in either the "cell" or "non-cell" locations. "Cell" locations are the areas inside the fabricated storage cells and "non-cell" locations are the storage locations created by arranging the fabricated storage cells in a checkerboard configuration. Hence the "non-cell" locations are the areas defined by the outside walls of the 4 adjacent "cell" locations.

The action statement applicable to fuel storage in the spent fuel pool requires that action must be taken to preclude the occurrence of an accident or to mitigate the consequences of an accident in progress. This is most efficiently achieved by immediately suspending the movement of fuel assemblies. Prior to the resumption of fuel movement, the requirements of the LCOs must be met. This requires restoring the soluble boron concentration and the correct fuel storage configuration to within the corresponding limits. This does not preclude movement of a fuel assembly to a safe position.

The surveillance requirements ensure that the requirements of the two LCOs are satisfied, namely boron concentration and fuel placement. The boron concentration in the spent fuel pool is verified to be greater than or equal to the minimum limit. The fuel assemblies are verified to meet the subcriticality requirement by meeting either the initial enrichment and burnup requirements of Table 3.9-1 through 3.9-5, or by using NRC approved methodology to ensure that $k_{eff} \leq 0.95$. By meeting either of these requirements, the analyzed accidents are fully addressed.

The fuel storage requirements and restrictions discussed here and applied in section 3.9.13 are based on a maximum allowable fuel enrichment of 4.75 weight% U-235. The enrichments listed in Tables 3.9-1 through 3.9-5 are nominal enrichments and include uncertainties to account for the tolerance on the as built enrichment. Hence the as built enrichments may exceed the enrichments listed in the tables by up to 0.05 weight% U-235. Qualifying burnups for enrichments not listed in the tables may be linearly interpolated between the enrichments provided. This is because the reactivity of an assembly varies linearly for small ranges of enrichment.

REFERENCES

1. "Regulatory Guide 1.13: Spent Fuel Storage Facility Design Basis", U.S. Nuclear Regulatory Commission, Office of Standards Development, Revision 1, December 1976.

2 "Design Objectives for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations", American Nuclear Society, ANSI N210-1976/ANS-57.2, April 1976.

Proposed Requirements: (Con't)

3. FSAR, Section 9.1.

4. Double contingency principle of ANSI N16.1-1975, as specified in the April 14, 1978 NRC letter (Section 1.2) and implied in the proposed revision to Regulatory Guide 1.13 (Section 1.4, Appendix A).

Current Requirements:

Technical Specification Reference: 5.6 Fuel Storage

Section 5.0 DESIGN FEATURES

5.6 Fuel Storage

CRITICALITY

5.6.1 The new and spent fuel storage racks are designed and shall be maintained with:

a. A k_{eff} equivalent to less than or equal to 0.95 when flooded with unborated water, which includes a conservative allowance for uncertainties as described in Section 9.1.2.3.1 of the FSAR, and

b. A nominal 21-inch center-to-center distance between fuel assemblies placed in the new fuel storage vault racks, and

c. A nominal 10.4-inch and a 9.125 inch center-to-center distance between fuel assemblies placed in Region 1 and Region 2 storage racks, respectively, in the spent fuel storage pool.

DRAINAGE

5.6.2 The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 745 ft. 7 in.

CAPACITY

5.6.3 The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1463 fuel assemblies (286 spaces in Region 1 and 1177 spaces in Region 2) having an initial enrichment less than or equal to 4.0 weight percent U-235.

Proposed Requirements:

Technical Specification Reference: 5.6 Fuel Storage

Section 5.0 DESIGN FEATURES

5.6 Fuel Storage

CRITICALITY

5.6.1 a. The spent fuel storage racks are designed and shall be maintained with $k_{eff} \leq 0.95$ if fully flooded with unborated water as described in Section 9.1 of the FSAR; and

b. The new fuel storage racks are designed and shall be maintained with $k_{eff} \leq 0.95$ if fully flooded with unborated water; and $k_{eff} \leq 0.98$ if moderated by aqueous foam as described in Section 9.1 of the FSAR.

DRAINAGE

5.6.2 The spent fuel storage pool is designed and shall be maintained to prevent inadvertent draining of the pool below elevation 745 ft. 7 in.

CAPACITY

5.6.3 The spent fuel storage pool is designed and shall be maintained with a storage capacity limited to no more than 1463 fuel assemblies (286 spaces in Region 1 and 1177 spaces in Region 2).

VIII.2 Proposed FSAR Modifications

Sections 4.3, Nuclear Design, and 9.1, Fuel Storage and Handling, are the only sections of the McGuire FSAR which will require modification as a result of the proposed technical specification changes detailed in this license amendment submittal.
Specific language will be developed upon approval of this amendment request. In general however, changes will focus on the following sub-sections:

4.3.2.6 Criticality of the Reactor During Refueling and Criticality of Fuel Assemblies

The discussion of the codes and methodology used in the criticality analysis would be updated to reflect the use of both the CASMO-3/SIMULATE-3 and SCALE/KENO Va methodologies.

9.1.1.3.2 Criticality Evaluation

Assumption number 5 in the listing of those made in evaluating criticality safety will be changed to reflect the increase in the upper enrichment limit to 4.75weight% with a tolerance of .05weight%.

9.1.2.2.3 Applicable Codes and Standards

The discussion on page 9-10 which references specific burnup requirements for unrestricted fuel storage in region 2, and describes storage restrictions for fuel not meeting these requirements will be changed. The revision will reference specific burnup requirements for restricted and unrestricted storage requirements for fuel being placed in either region 1 or region 2.

9.1.2.3.3 Normal Storage

The statement which follows the assembly parameters tabulation stating that no U-235 burnup is assumed for region 1 storage will no longer be accurate. The proposed license amendment does utilize burnup credit for region 1 storage of fuel with initial enrichments exceeding 4.19 weight%.

9.1.2.3.5 Criticality Calculations

This section of the McGuire FSAR discusses the calculational methodology employed to ensure criticality safety for fuel storage. This section will be modified to reference the new methodology used to support the proposed license changes and being requested for approval as part of this submittal.

9.1.3.2 Spent Fuel Cooling System

While the spent fuel cooling system will not be modified as a result of this submittal, the normal and abnormal heat load assumptions will change as a result of the higher anticipated discharge burnups. The results of an analysis based on these heat loads will be reflected in this section.

IX ADMINISTRATIVE CONTROLS

Fuel storage restrictions currently applicable to the two spent fuel pools at MNS include both the qualification requirements as stated in the technical specifications and the administrative controls to ensure proper selection and placement of new and irradiated fuel in the two storage regions. These controls include individual assembly record keeping and review to accurately track and verify reactivity-related fuel characteristics, specific fuel handling procedures and restrictions, and the use of cell blocking devices to preclude fuel placement in cells which must remain empty in a checkerboard loading arrangement. For the most part, the procedural portions of the existing restrictions will be retained under the proposed technical specification revision with only the qualification requirements being modified to accommodate the higher fuel enrichments and the new fuel loading patterns being introduced.

IX.1 Current Loading Restrictions

The current Technical Specifications identify characteristics and associated loading restrictions for 3 separate fuel categories as follows:

Fuel Category	Applicable Region	Loading Pattern Restriction
1A	Region 1	None
2A	Region 2	None
2B	Region 2	50% Fuel / 50% Empty Cells

IX.2 Proposed Loading Restrictions

The proposed technical specification revision will replace the above fuel categories with 5 modified fuel categories which are listed below with their respective loading restrictions:

Fuel Category	Applicable Region	Loading Pattern Restriction
1A	Region 1	None
1B	Region 1	75% Fuel / 25% Fillers
2A	Region 2	None
2B	Region 2	50% Fuel / 50% Fillers
2C	Region 2	50% Fuel / 50% Empty Cells

Each of fuel categories 1A, 2A, and 2B, will have a corresponding burnup curve as discussed in section VIII which represents the maximum reactivity level allowed by that category. Categories 1B and 2C are simply limited to new or irradiated fuel with initial enrichments at or below 4.75 weight% (nominal).

Categories 1B and 2C which respectively require the most restrictive loading pattern in each region are intended to accommodate any new or discharged assemblies which do not qualify for the less restrictive loading patterns of categories 1A, 2A, and 2B. The primary use for these categories will be temporary storage of new (fresh) fuel assemblies above 4.19 weight % initial enrichment.

IX.3 Filler Assembly Requirements

As noted above, the designated loading patterns for categories 1B and 2B require the placement of "filler" assemblies into appropriate locations of the loading pattern. Consequently, 2 additional fuel subcategories are identified for the purpose of defining qualification requirements for these fillers. The filler categories are summarized as follows:

Fuel Category	Application
1Bf	Region 1 Filler Fuel
2Bf	Region 2 Filler Fuel

As is the case for fuel categories 1A, 2A, and 2B, qualification of fuel for placement into these "filler" fuel categories is governed by separate burnup curves which are detailed in section VIII.

IX.4 Pre-Staging of Checkerboard Areas

The added flexibility provided by this proposed license amendment, while allowing for increased storage efficiency, does add some degree of complexity through the allowance of 2 loading configurations in region 1, and 3 loading configurations in region 2. It should be noted, however that the majority of the spent fuel discharges from the McGuire reactors will qualify for unrestricted storage in either region 1 or region 2, thus keeping the quantity of fuel subject to a misplacement accident to a minimum.

Procedural controls to ensure correct placement of new and irradiated fuel will be carefully developed and implemented through ongoing interactions between the fuel management organization and the McGuire station reactor engineering group. Additionally, specific pre-staging of the filler assemblies and empty cell blocking devices required for the three restricted storage configurations will occur as needed to further protect against fuel misplacement. Specific pre-staging plans for the three possible restricted configurations are as follows:

> Category 1B fuel assemblies which are required to be placed into a 75% (3 of 4) loading pattern will only be moved into the region 1 area of the fuel pools after the appropriate number of "filler" assemblies needed for this pattern have been qualified and put in place. This clearly identifies the region 1 rack locations that can safely be used for storing these assemblies, thus precluding fuel assembly mis-loading.

Category 2B fuel assemblies which are required to be placed into a 50% (2 of 4) loading pattern will only be moved into the region 2 area of the fuel pools after the appropriate number of "filler" assemblies needed for this pattern have been qualified and put in place. This clearly identifies the region 2 rack locations that can safely be used for storing these assemblies, thus precluding fuel assembly mis-loading.

Category 2C fuel assemblies which are required to be placed into a 50% (2 of 4) loading pattern will only be moved into the region 2 area of the fuel pools after the appropriate number of cell blocking devices needed for this pattern have been put into place. This clearly identifies the region 2 rack locations that can safely be used for storing these assemblies, thus precluding fuel assembly mis-loading.

Additional misloading protection is provided by the fact that the restricted storage regions will generally be assembled in somewhat isolated areas of the pool such as corners, along walls, or at one end of the pool. Consequently, ongoing need for fuel movement into, out of, or within these areas are also minimized.

When fuel movement in or out of these restricted regions does occur, or if the entire region must be relocated to another area of the pool, quality-verified procedures will be used to direct the actual fuel movements. Such QA-1 procedures, combined with operator awareness and careful visual verification eliminates the need for interlocking devices or special fuel labeling that would prevent inadvertent movement of a filler assembly. Misplacement of fuel in the 50% checkerboard configuration is highly unlikely due to the visual contrast and the special handling requirements of the cell blocking devices.

IX.5 Pre-Staging of Interface Restrictions

As summarized in section VII.3 and discussed in detail in Appendix A, the fuel loading patterns required for fuel categories 1B and 2C have specific restrictions related to the interfaces that can exist with other loading patterns. These interface restrictions will be accommodated through appropriate orientation of the pre-placed filler assemblies and/or cell blocking devices required for those patterns. Where a category 2C area is not large enough to span across a full module, additional cell blocking devices will be used to create the required empty row of storage cells to sufficiently isolate the area.

Proper identification and placement of fuel assemblies with respect to these categories will occur through administrative review of SNM accountability records, qualification against applicable burnup vs. enrichment curves, and finally through administratively controlled procedures which will govern actual fuel placement. As discussed above, the accountability system to be used for fuel characterization and the existing procedural controls for moving fuel within and between regions, for movement of fuel in and out of the core, and for moving fuel between spent fuel pools will all be retained. Revised burnup vs. enrichment curves which determine fuel category are detailed in the proposed technical specifications found in section VIII.

Appendix A

Methodology for Development of Region Interface Restrictions

APPENDIX A REGION INTERFACE RESTRICTIONS METHODOLOGY

This appendix provides supplemental information on the methodology used to establish the necessary interface restrictions for the various fuel storage regions in the McGuire Spent Fuel Pools as discussed in sections VII and IX of this submittal. The intent of this analysis is to maximize the utilization of the storage cells along these interfaces while ensuring against excessive interaction between these regions.

A.1 Methodology

The analysis method that ensures the criticality safety of fuel assemblies in the spent fuel storage rack uses the CSAS25 module contained in the Criticality Analysis Sequence No. 4 (CSAS4). CSAS4, along with the 123GROUPMTH cross section library are part of the SCALE-3 system of codes. CSAS25 consists of two cross section processing codes (NITAWL and BONAMI) and a 3-D monte carlo code (KENO Va) for calculating the effective multiplication factor for the system. A set of 21 critical experiments has been analyzed using the CSAS25 module with the 123GROUPMTH library to demonstrate its applicability to criticality analysis and to establish a method bias and variability. The experiments analyzed represent a diverse group of water moderated , oxide fuel arrays separated by various materials (stainless steel, Boral, water, etc.) that are representative of LWR fuel shipping and storage conditions, including the McGuire spent fuel pool.

Acceptable interface boundary conditions between storage configurations were determined by varying the boundaries between various storage regions to determine the worst case configurations for coupling between assemblies in different regions. The boundaries were then reflected to simulate an infinite array. The k_{eff} of these infinite boundary arrays were compared to the base k_{eff} of infinite arrays of either fuel storage region creating the boundary. If the infinite boundary array k_{eff} did not represent an increase in the k_{eff} of the regions making the boundary, then no storage restrictions were imposed at the interface. When the worst case did represent an increase, conservative storage restrictions were applied.

A.2 Assumptions

As in most criticality analysis of this type, credit is taken for the inherent absorption in full length structural materials. No burnable poisons, control rods, or supplemental neutron poisons are assumed to be present. All assemblies are assumed to be unirradiated Babcock & Wilcox (B&W) Mk BW 17X17 fuel with various initial enrichments. Each fuel assembly is treated as a heterogeneous system with the fuel pins, control rod guide tubes, and instrument guide tube modeled explicitly and the moderator is pure, unborated, full density water.

The base model for all region 2 checkerboard schemes are modeled as groups of four storage locations with the higher enrichment assemblies being modeled in the non-cell locations. The boundaries between checkerboard regions are modeled as small reflected groups in an attempt to determine worst case coupling configurations between assemblies of differing initial enrichments. The acceptability of various region interface configurations was determined by comparison to the k_{eff} of infinite models of the individual regions which share the boundary.

A.3 Background

The present three region configuration for each of the McGuire spent fuel pools does not consider boundary conditions because each region is separated from the others by a minimum of 15 cm of water. The separation between region I and region II is due to a physical gap between the modules. The separation between region II qualified storage and the checkerboard region containing unqualified fuel is achieved by the Technical Specification requirement to maintain an empty row of cells between the two regions. One of the objectives of this license submittal is the optimization of SFP storage and therefore the elimination of empty rows or empty storage cell requirements.

A.4 Proposed Storage Regions and Boundaries

Two of the proposed five storage regions that will be established, will be located within the existing region 1 rack modules. These will be called regions 1A and 1B. The other three will be established within the confines of the existing region 2 rack modules and be referred to as region 2A, 2B, and 2C.

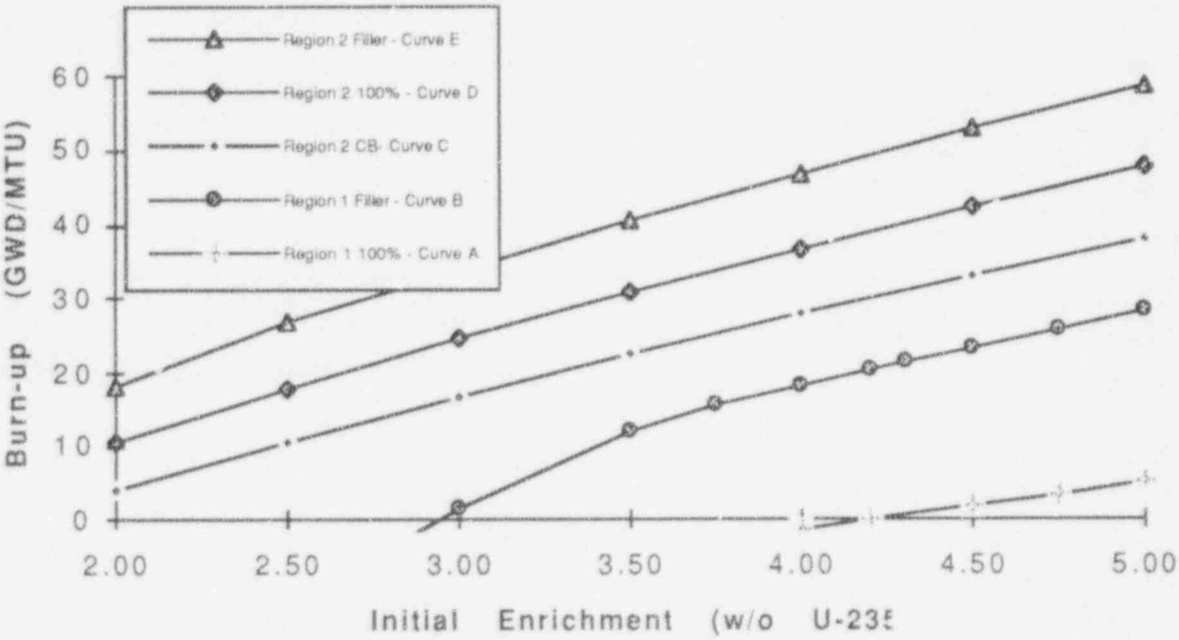
Region 1A will allow for the 100% storage of qualified fuel. To be qualified for this region, a fuel assembly must have either an initial enrichment no greater than 4.19 weight% or a minimum burnup as defined by the region 1A acceptance curve. This is shown as Curve A in figure A-1. Region 1B is made up of those assemblies (up to initial enrichments of 4.75weight%) not meeting the region 1A requirements but still requiring storage in the region 1 rack modules. Region 1B assemblies must be stored in a 75% loading configuration with either empty cells or appropriately qualified filler assemblies. This configuration is illustrated in figure A-2. The acceptance criteria for the filler assemblies is shown as Curve 1Bf in figure A-1.

Acceptance curves for region 2A and 2B are also shown in figure A-1 as Curve D and Curve C respectively. Region 2A allows for a 100% storage configuration of fuel with equivalent enrichments of up to 1.5weight%. Assemblies not meeting region 2A requirements will be placed in a region 2B configuration which requires a 50% checkerboard arrangement with filler assemblies as illustrated in figure A-3. The acceptance criteria for the region 2B filler assemblies is shown as Curve E in figure A-1. Though none are anticipated from normal operations, fuel assemblies discharged below the acceptance curve for region 2B (i.e. greater than 1.76weight% equivalent) may be stored in either a 50/50 configuration with empty water cells or, if they qualify, as filler fuel assemblies in region 1B.

The methodology used to generate all of the acceptance curves in figure A-1 is summarized in section VI and detailed in Appendix B.

Figure A-1

Acceptance Curves
for
McGuire Spent Fuel Storage Regions



Minimum Acceptance Curve Summary

Curve	Applicable Region	Equivalent Enrichment
A	Region 1A	4.19 weight%
B	Region 1B Fillers	2.83 weight%
C	Region 2B	1.76 weight%
D	Region 2A	1.55 weight%
E	Region 2B Fillers	0.86 weight%

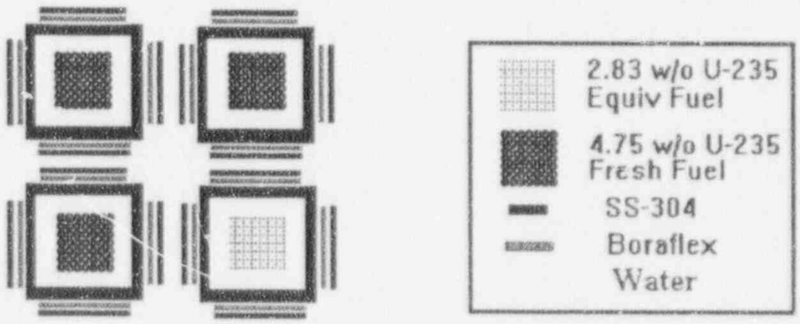
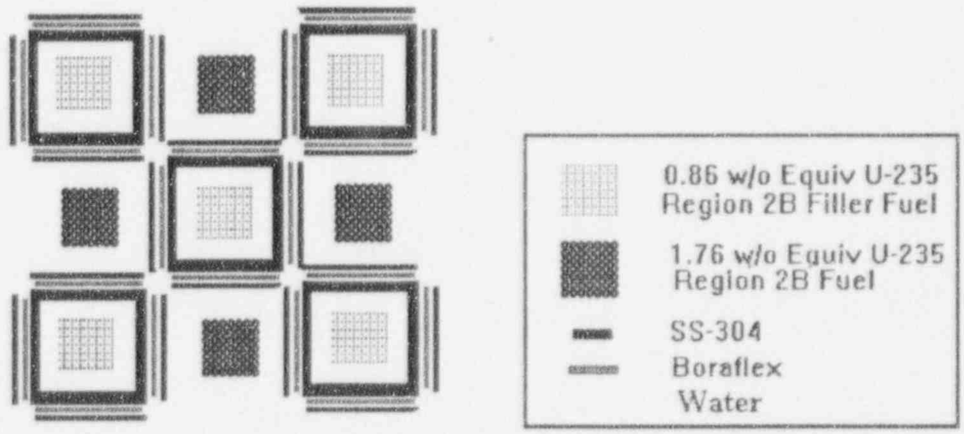


Figure A-2

Region 1B - Checkerboard Region



<u>Figure A3</u>
Region 2B 50% Checkerboard Configuration with Filler Fuel

To analyze the various possible interface configurations, KENO Va models of both spent fuel pool rack designs, including the variations between cell and non cell geometry's of region 2, were developed. The cells (loaded with fuel assemblies of appropriate enrichments) are then arranged in the desired storage configurations.

A.5 Region 1 Boundaries

There is only one possible boundary between fuel storage regions in the Region 1 rack modules. As discussed previously, region 1B allows for storage of fresh fuel with enrichments in excess of 4.19 weight%. This region consists of a 75 % (3 of 4) region 1B fuel and 25% region 1B filler fuel (1 of 4) checkerboard configuration as shown in figure A-2. For this analysis, region 1B fuel was conservatively modeled as 4.75weight% fresh fuel. Region 1B filler fuel is defined as fuel that meets the region 1B filler acceptance curve (Curve B) shown in figure A-1 which was modeled as 2.83weight% fresh fuel. If this group of four is repeated periodically the pattern forms alternating rows of 100% 4.75weight% fuel and mixed rows of 4.75/2.83 weight% fuel in both X and Y directions. This pattern is illustrated in figure A-4 below.

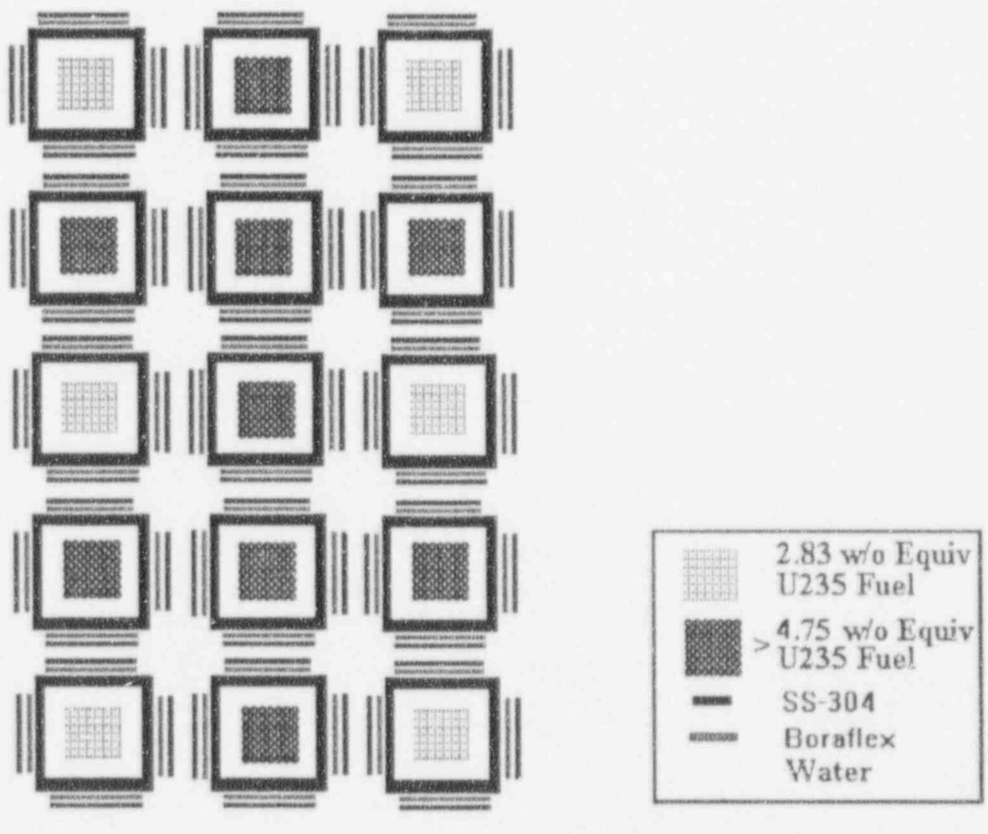


Figure A-4
Region 1B Boundary Condition

The region 1B configuration was modeled directly adjacent to the region 1A configuration using both region 1B row "types" shown above as the interface between the regions. Criticality analysis using these two models indicated a need to administratively require a row of alternating 2.83 / 4.75 weight% fuel assemblies to be maintained as the boundary. Based on this requirement, figure A-4 shows the appropriate conditions necessary to create an acceptable boundary between regions 1A and 1B.

A.6 Region 2 Boundaries

The technical specification amendments proposed in this submittal would create the potential for three distinct fuel storage regions in the region 2 rack modules. All possible interfaces between these regions were analyzed to determine the need for interface restrictions.

KENO analysis of adjacent region 2A and 2B fuel loading patterns revealed that no interface restrictions are necessary. Worst case models depicting infinite arrays of small islands of the region 2B checkerboard configuration surrounded on four sides by 1.55 weight% fuel (region 2A) did not cause a change in the overall k_{eff}.

Where the interface between regions 2A and 2B are unrestricted, allowing either region to bound the other on all four sides, the calculations reveal a need for restrictions whenever a region 2C loading pattern exists in the spent fuel pool. Specifically, the boundaries between regions 2B and 2C, and between regions 2A and 2C will be restricted. The required storage restrictions for these two boundary conditions are identical, allowing only one side or two **opposite** sides of one region to be bounded by the other. The other two sides must be bound by either the fuel pool wall or an empty row of cells.

The region 2C interface restrictions are illustrated in figure A-5 using adjacent region 2A and 2C configurations as an example. Figure A-5 shows region 2C fuel bounded on two opposite sides by region 2A fuel. A third side is bounded by the fuel pool wall and the fourth side is bounded by empty water cells. Storage restrictions at the interface between region 2B and 2C storage configurations would be identical.

In both of these cases, region 2C was modeled as some number of rows(infinite in the Y direction) bounded on two opposite sides by some other number of rows (also infinite in the Y direction) of region 2A and 2B fuel. Each boundary condition also includes an analysis of the two sides being bounded by concrete to simulate the fuel pool walls. The empty row of cells serving as a boundary was not explicitly modeled since it was judged to represent an infinite water path that would prevent neutron interaction.

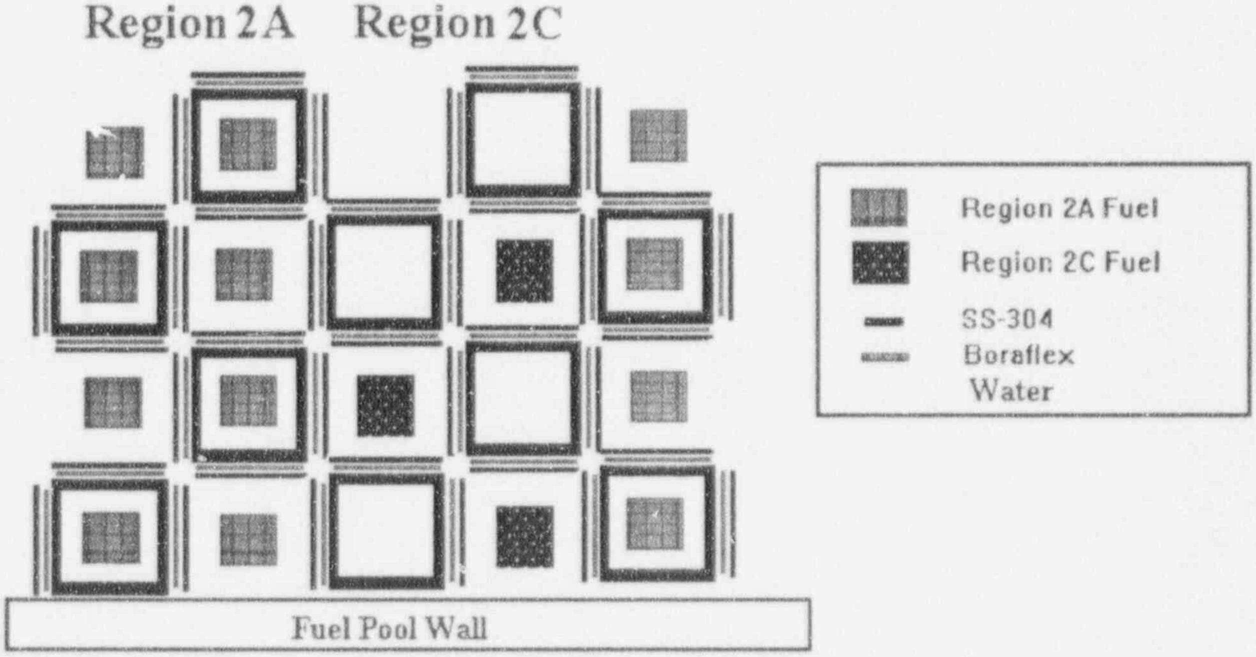


Figure A-5

Restrictions for Region 2A - 2C Interface

A.7 Conclusions

This appendix documents the interface restrictions required between the five regions of spent fuel storage that will be instituted in the McGuire spent fuel pool. The CSAS25 module in the SCALE-3 system of codes was used to determine the necessary loading restrictions. CSAS25 utilizes the 123GROUPGMTH cross sectional library, Nitawl and Bonami as cross section processors, and Keno Va to determine the k_{eff} of a given interface configuration.

Acceptable interface configurations were determined by varying the boundaries between various storage regions and reflecting these boundaries to simulate an infinite array. The k_{eff} of these infinite boundary arrays were compared to the base k_{eff} of infinite arrays of the individual fuel storage regions being assessed. If the infinite interface array did not represent an increase in K_{eff}, then no interface loading restrictions were imposed. For those boundaries that do carry restrictions, the governing criteria were 1) to assure that no increase in the nominal k_{eff} is created at the boundary, and 2) to allow for the most flexibility in the building of regions and boundaries and thus promote the optimization of spent fuel storage. A summary of the resulting interface restrictions are provided in Table A-1 below.

Table A-1

Summary of
Region Interface Loading Restrictions

Interface	Restrictions
Region 1A and 1B	Row of region 1B bounding region 1A must be a row of alternating region 1B fuel types and region1B filler locations.
Region 2A and 2B	No Interface Restrictions
Region 2A or 2B and 2C	At least 2 opposite sides of region 2C shall be bounded by either a row of empty water cells or the fuel pool wall. The remaining side(s) may be either region 2A or region 2B or both.

Appendix B

<u>Methodology</u>
<u>for</u>
<u>Burnup Credit Analysis</u>

APPENDIX B METHODOLOGY FOR BURNUP CREDIT ANALYSIS

B.1 Nominal Reactivity Calculation

The methodology for burnup credit analysis starts with the fuel storage rack drawings to construct a predictive computer model. This model in the form of an input deck calculates the reactivity level of the desired fuel storage configuration for the racks. As an example for this appendix, a 100% fuel loading storage configuration from Duke Power Company's McGuire Region 1 storage racks is analyzed. The 100% loading configuration places a fuel assembly in every storage location without the use of any checker boarding scheme that requires empty cells (water-holes) or depleted (filler) fuel assemblies.

Table B-1 below provides typical nominal K-effective values for fuel with varying initial enrichments stored in the 100% loading configuration. The reactivity of the storage configuration is shown as a function of increasing amounts of burnup. The curves are generated through in-core depletion of the applicable fuel assembly using CASMO followed by storage rack-specific analysis of the depleted fuel. CASMO models an infinite array of a single fuel type. SIMULATE must be used if dissimilar fuel assemblies are analyzed, as is the case for the more complex storage configurations discussed in section 5.0 of this appendix. Both CASMO and SIMULATE compute reactivity versus burnup.

Table B-1

Nominal Reactivity of Region 1 Fuel Racks with 100 % Storage Configuration

Burnup	Kmax	4.0 w/o	4.2 w/o	4.5 w/o	4.75w/o	5.0 w/o
0	0.92918	0.92053	0.92942	0.94166	0.95098	0.95961
5	0.92516	0.88297	0.89218	0.90512	0.91487	0.92394
10	0.92114	0.84895	0.85878	0.87255	0.88303	0.89279
15	0.91784	0.81638	0.82674	0.84126	0.85243	0.6288
20	0.91739	0.78524	0.79612	0.81146	0.82328	0.83423
25	0.91694	0.75618	0.76748	0.78343	0.79581	0.80743
30	0.91649	0.72742	0.73912	0.75567	0.76859	0.78084
35	0.91604	0.69961	0.71158	0.72864	0.74203	0.75445
40	0.91560	0.67245	0.68446	0.70180	0.71556	0.72883
45	0.91515	0.64643	0.65828	0.67582	0.68974	0.70293
50	0.91470	0.62192	0.63336	0.65039	0.66422	0.67785
55	0.91425	0.59921	0.61004	0.62635	0.64004	0.65316
60	0.91380	0.57870	0.58860	0.60390	0.61682	0.62988

Table B-1 provides the data to construct a reactivity versus burnup plot for each of the analyzed enrichment values. Once the fuel depletion data is calculated, generation of the desired fuel storage qualification curve requires a rack-specific maximum reactivity curve as represented by the K_{max} column in Table B-1.

B.2 Biases And Uncertainties

Generation of a rack specific maximum reactivity curve requires the computation of many biases and uncertainties. The maximum reactivity curve is calculated by subtracting the required biases and uncertainties from the regulatory reactivity limit for fuel storage ($K_{eff} = 0.95$ for spent fuel storage) as is shown in the equation below.

$$K_{max} = K_{reg\ lim} - \Delta K$$

Through the summing of the biases and uncertainties, the maximum reactivity as a function of burnup can be plotted for each desired storage configuration. Table B-2 lists typical new fuel biases and uncertainties which must be considered. The methodology bias and uncertainty are independent of rack design. The mechanical uncertainty is rack specific and must be re-calculated for each storage rack analyzed. The Boraflex shrinkage and self-shielding values are computed based the amount of Boraflex in a rack and are rack specific.

Table B-2

Typical New Fuel Biases and Uncertainties

	Bias or Uncertainty	Δ K
ΔK_{cb}	Methodology Bias	-0.00189
ΔK_{bs}	Boraflex width shrinkage Bias	0.00417
ΔK_{ss}	Self-Shielding Bias	0.00150
ΔK_{bsa}	Boraflex axial shrinkage Uncertainty	0.00138
ΔK_{cu}	95/95 Methodology Uncertainty	0.01080
ΔK_{me}	Mechanical Uncertainty	0.01311

B.2.1 Methodology Bias and 95/95 Methodology Uncertainty

The results for the criticality methodology are validated by comparison to measured results of fuel storage critical experiments. The criticality experiments used to benchmark the methodology were the Babcock and Wilcox close proximity storage critical experiments performed at the CX-10 facility. The B&W critical experiments used are specifically designed for benchmarking reactivity calculation techniques. The experiments are analyzed, and the statistical accuracy of the calculated reactivity results are assessed. The integral transport theory code CASMO-3, a data processing code TABLES-3, and the nodal diffusion theory code SIMULATE-3 are used to analyze the experimental configurations from a criticality standpoint.

The criticality experiments examined have similar nuclear characteristics to spent fuel storage and are applicable to conditions encountered during the handling of LWR fuel outside reactors. Table B-3 shows a typical calculational uncertainty and code bias for the CASMO3/ TABLES3/SIMULATE3 methodology when applied to fuel storage calculations.

Table B-3

Typical Benchmark Results and Uncertainties

Standard Deviation	0.00371
95/95 One-Sided Tolerance Factor	2.911
95/95 Methodology Uncertainty	0.01080
Methodology Bias	-0.00189

The methodology uncertainty for the experiments is calculated by multiplying the standard deviation times the 95/95 one sided tolerance factor. There are no significant trends in the results with respect to moderator soluble boron concentration, array spacing, or boron level in the isolation sheets as shown in Table B-4.

Table B-4

CASMO3/TABLES3/SIMULATE3

Benchmarking Results

Core	Soluble Boron	Moderator Temp	Separation Spacing (cm)	Poison Sheet (%B)	Ki calc	K meas	Bias
2	1037	18.5	0	n/a	1.00280	1.0001	-0.00270
3	764	18	1.636	n/a	1.00337	1.0000	-0.00337
9	0	17.5	6.544	n/a	1.00091	1.0030	0.00209
10	143	24.5	4.908	n/a	0.99933	1.0001	0.00077
11	514	26	1.636	SS	1.00525	1.0000	-0.00525
13	15	20	1.636	1.614	1.00914	1.0000	-0.00914
14	92	18	1.636	1.257	1.00470	1.0001	-0.00460
15	395	18	1.636	0.401	0.99627	0.9988	0.00253
17	487	17.5	1.636	0.242	0.99911	1.0000	0.00089
19	634	17.5	1.636	0.1	1.00030	1.0002	-0.00010
				avg K-calc	1.00212	st.dev calc	0.00371
				avg Kmeas	1.00023	avg bias	-0.00189

A further indication of the accuracy of the process comes from comparisons to the results of other benchmarking efforts of the same experiments. The calculated uncertainty and bias of the code, compares favorably with values presented in other calculations as shown in Table B-5.

Table B-5

Comparative Rench marking Results

Core	Duke Cas/Sim	YAEC Cas/Sim	YAEC Cas/PDQ	Duke Keno IV			YAEC Keno IV		
2	1.00280	1.00284	1.00325	1.0011	+/-	0.0038	1.00085	+/-	0.00294
3	1.00337	1.00335	1.00622	0.9987	+/-	0.0038	0.99886	+/-	0.00336
9	1.00091	0.99813	1.00192	0.9869	+/-	0.0046	0.99116	+/-	0.00365
10	0.99933	0.99823	1.00612	0.9862	+/-	0.0049	0.98551	+/-	0.00362
11	1.00525	1.00245	1.00562	1.0062	+/-	0.0039	1.00673	+/-	0.00360
13	1.00914	1.00313	1.00208	1.0036	+/-	0.0054	1.01049	+/-	0.00402
14	1.00470	0.99882	0.99863	0.9960	+/-	0.0040	1.00544	+/-	0.00367
15	0.99627	0.99250	0.99381	0.9919	+/-	0.0037	0.99344	+/-	0.00344
17	0.99911	0.99569	0.99740	0.9978	+/-	0.0040	1.00272	+/-	0.00314
19	1.00030	0.99689	0.99879	0.9929	+/-	0.0040	0.99591	+/-	0.00276
K -avg	1.00212	0.99920	1.00138	0.9955			0.99911		
St dev	0.00371	0.00367	0.00416	0.0065			0.0065		

B.2.2 Boraflex Width Shrinkage Bias and Boraflex Axial Shrinkage Uncertainty

Special neutron poison verification testing was performed on irradiated fuel storage racks. The testing process accuracy was verified using a special mock fuel storage cell specially designed for benchmark testing purposes. The benchmark testing data was evaluated using standard statistical methods. The test process instrumental bias and uncertainty was established, and the test data results were evaluated statistically.

Based on the above verification testing, the nominal and worst case Boraflex shrinkage conditions in the storage racks were established. These values included the test process bias and uncertainty. Fuel storage array reactivity impacts were evaluated using sensitivity studies performed by the rack manufacturer.

B.2.3 Self-Shielding Bias

This bias accounts for the Boron Carbide (B_4C) particulate self shielding effects that result when either SCALE/KENO or CASMO/SIMULATE methodology are used in analyzing the criticality of fuel storage racks. The rack poison material (Boraflex) is made up of B_4C particles suspended in a silicate binding. Both methodologies assume that the B_4C is homogenized within the Boraflex. This approximation neglects the self shielding effects caused by the B_4C particles and causes the codes to over predict the worth of the poison sheets. Therefore, the approximation introduces a non-conservative element in the calculation.

To quantify the non-conservative element, a total of four self shielding factors are calculated as a function of energy. These factors were then used to determine four separate changes in the neutron transmission probabilities (DP_T) through the sheets caused by self shielding effects. These DP_Ts were then converted to biases using the reaction rates in the Boraflex along with the worth of the Boraflex sheets.

B.2.4 Mechanical Uncertainty

The mechanical uncertainty calculation considers those elements of the model which can vary from the stated design value to the actual manufactured value. Parameters which must be considered are fuel assembly center to center (CTC) spacing, canister envelop, fixed poison width, fixed poison thickness, fuel stack density, and fuel enrichment. Criticality calculations are made at both the maximum and minimum values of each parameter. The difference between the maximum and minimum values is averaged. The final value for the mechanical uncertainty is the root sum of squares of these averages.

B.2.5 Combination of New Fuel Biases and Uncertainties

Once the new fuel biases and uncertainties are known, they are combined in the following equations to determine an aggregate value.

$$\Delta K_{eff} = \Delta K_{cb} + \Delta K_{bs} + \Delta K_{ss} + \sqrt{(\Delta K_{bsa})^2 + (\Delta K_{mu})^2 + (\Delta K_{me})^2}$$

Typical Values:

$$\Delta K_{eff} = -0.00189 + 0.00417 + 0.00150 + \sqrt{(0.00138)^2 + (0.01080)^2 + (0.01311)^2}$$

$$\Delta K_{eff} = 0.020822$$

In addition to the new fuel biases and uncertainties, there is also an added bias and uncertainty associated with fuel burnup. Therefore, the final equation for the pool reactivity limit is written as a function of burnup.

B.2.6 Burnup Bias and Uncertainty

A value for the burnup uncertainty and bias is required to quantify the reactivity of burned nuclear fuel assemblies. Table B-6 shows the magnitude of two typical burnup uncertainties associated with using CASMO3 / TABLES3 / SIMULATE3 for criticality analysis.

Table B-6

Burnup Uncertainty

$\Delta K_{Exposure\ Reactivity\ Uncertainty}$	0.00448
$\Delta K_{Burnable\ Absorber\ Reactivity\ Uncertainty}$	0.01

The first penalty accounts for uncertainties in the reactivity due to uncertainties in the burnup of the assembly, while the second penalty accounts for the reactivity holddown effect of lumped burnable absorbers.

The exposure reactivity uncertainty accounts for the uncertainty on the assembly burnup. Since the final burnup qualification curves provided in the new Technical Specifications are based on a code calculated burnup, the uncertainty in that calculated burnup must be considered. Rather than determining the uncertainty on the actual burnup, the uncertainty on reactivity due to burnup was applied to account for the burnup uncertainty. Reactivity measurements are performed at the plant and compared to predictions on a regular basis. The comparisons determine the errror in the predicted versus actual reactivity of the core at hot full power conditions. The results of these comparisons were tabulated for 18 cycles of Duke Power operating experience for a total of 259 data points. This collection of data covers a wide range of burnups. A 95/95 one-sided tolerance was applied to this data to determine the maximum reactivity error associated with the burnup of the fuel. Since this represents the maximum error due to burnup, this penalty is applied as a function of burnup. Beyond this value, the full penalty is applied. The maximum reactivity equation then combines the regulatory reactivity limit for fuel storage with the new fuel and burnup biases and uncertainties as shown below.

Two other variables considered in developing this methodology were the axial burnup profile which exists in varying magnitudes as a result of reduced neutron flux at the top and bottom portions of the core, and the effects of having fuel inserts (i.e. burnable poison rods, control rods, etc.) present in the assemblies. Preliminary assessment of the axial burnup profile indicated this to be a very insignificant impact on the burnups required for qualification. With respect to the fuel insert concern, despite the reduction in available B-10, the reduced moderator creates a more dominant effect at the boron concentrations typical for the MNS station. Consequently, preliminary analyses actually indicate a reduced reactivity effect caused by the components. As a result of these preliminary assessments, no additional biases or uncertainties were included in the final analyses or in th resulting burnup requirements guidelines.

Two pool maximum reactivity equations are required because of the effect of lumped burnable poisons (LBP). The pulling of a LBP after a given burnup creates a one time reactivity insertion. To compensate for the added reactivity, a penalty of 0.01 is added to the maximum reactivity equation. The application of this penalty is applied as a function of burnup until a pre-determined limit is attained, typically 14 GWD/MTU. Beyond this value, the full penalty is applied. The maximum reactivity equation then combines the regulatory reactivity limit for fuel storage with the new fuel and burnup biases and uncertainties as shown in section B.3 on the next page.

B.3 Maximum Enrichment Curve - Burnup vs. Reactivity

The equations shown below represent the behavior of the maximum enrichment for two separate burnup ranges. When plotted together, they provide the maximum enrichment curve for the chosen storage configuration and rack design.

Kmax = Regulatory Pool Limit - (New Fuel Biases + Uncertainties) - (Burnup Biases + Uncertainties)

[For Burnup ≤14 GWD/MTU] :

$$K_{max} = 0.95 - (0.02082) - \frac{0.00448 * Burn-up}{50} - \frac{0.01 * Burn-up}{14}$$

$$K_{max} = 0.92918 - \frac{0.00448 * Burn-up}{50} - \frac{0.01 * Burn-up}{14}$$

[For 14 < Burnup < 50 GWD/MTU] :

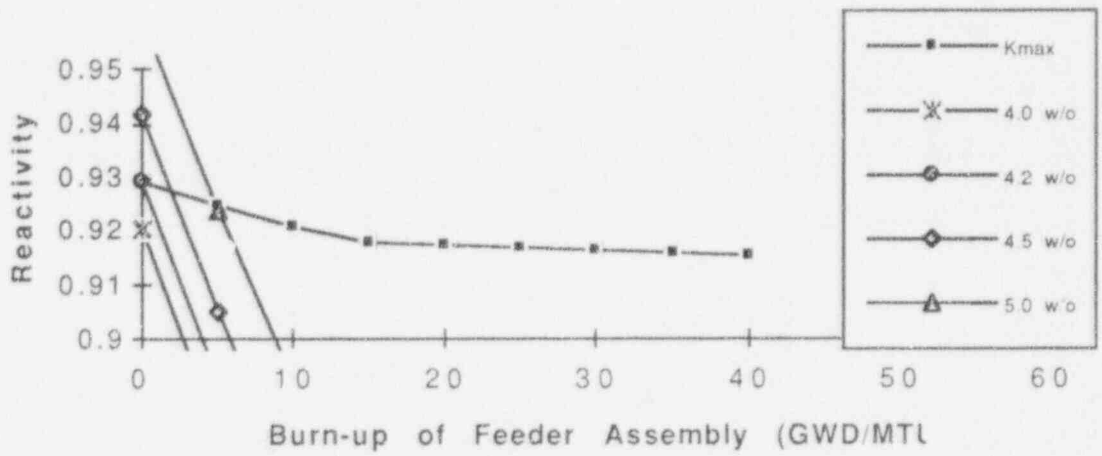
$$K_{max} = 0.95 - (0.02082) - \frac{0.00448 * Burn-up}{50} - 0.01$$

$$K_{max} = 0.91918 - \frac{0.00448 * Burn-up}{50}$$

The above equations when plotted together provide the maximum enrichment curve for the chosen storage configuration and rack design. The multiple fuel depletion curves with the maximum enrichment curve are shown in Figure B-1 on the following page. The intersection of the curves provides data points for generating a burnup versus enrichment curve.

Figure B-1

Maximum Enrichment and Fuel Burnup Curves

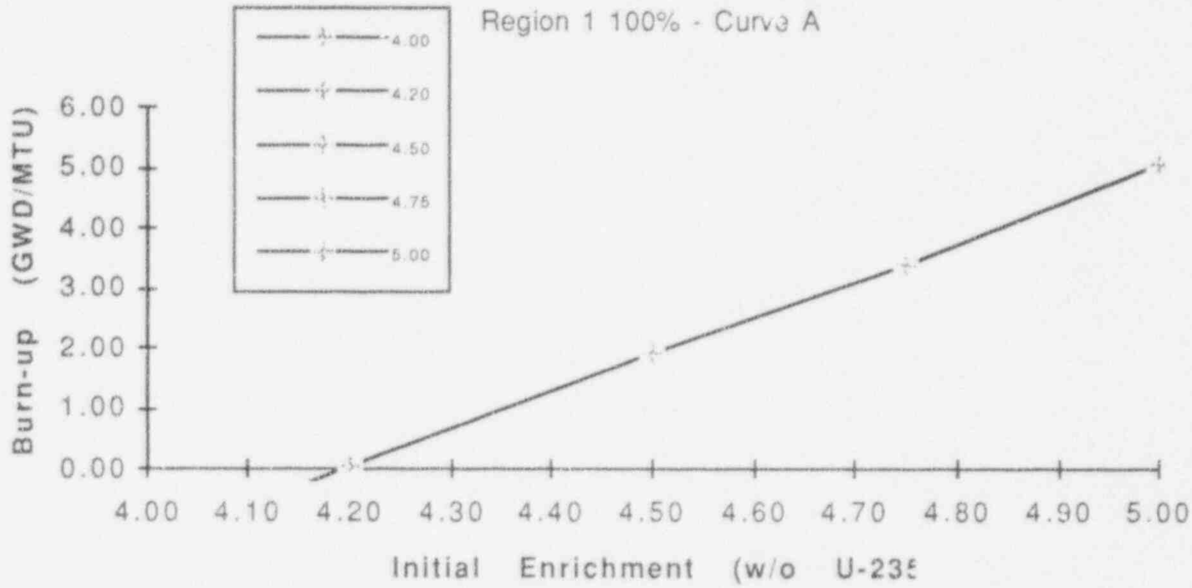


B.4 Qualification Curve - Burnup vs. Initial Enrichment

The next part of the process is the generation of a burnup versus initial enrichment curve. The solution for the intersection of the curves in Figure B-1 is performed by taking the maximum reactivity equations and solving them simultaneously with the linear regressions of the fuel specific depletion curves. To eliminate the effect of the non-linearities of the curves, the range of the linear regression is reduced to include only the two or three points that surround the intersecting curve. The number of points depends on the distribution. Usually only two points are required; however, if one of the points falls very close to the intersection point, then an additional point is added to compensate for the unevenness in the spread. The solution of the system of simultaneous equations provides the data for the qualification curve which is plotted in Figure B-2 below.

Figure B-2

Qualification Curve for 100% Storage Configuration



The curve in Figure B-2 show the minimum amount of burnup required to quality fuel for storage as a function of the fuel's initial enrichment. A fuel assembly qualifies if it falls <u>above</u> the curve for that storage configuration.

B.5 Generation of Multiple Qualification Curves

The need to store unqualified, highly reactive, fuel assemblies or the need for additional storage flexibility requires the use of multiple storage configurations. Additional storage configurations require multiple qualification curves.

The example in Figure B-2 has an upper enrichment limit of 4.19 w/o for fresh fuel. In order to store fuel enrichment higher than 4.19 w/o, a checkerboard loading pattern is required. The premise behind the checkerboard loading configuration is that unqualified (high reactivity) fuel assemblies can be stored with less reactive (filler) fuel assemblies so that the combined reactivity meets storage qualification requirements. Checkerboarding patterns can use either one or two filler assemblies in a group of four storage cells. For this example a 75 % checkerboard is studied where one filler is used with three high reactivity fuel assemblies.

The same process used to generate the 100 % storage configuration qualification curve is used to produce the filler qualification curve. The same CASMO computer model is used; however, SIMULATE must be used to pair different fuel assemblies into a combined reactivity calculation. In order to generate the filler qualification curve, a multi-step process must be followed which is detailed below.

1) Select the most reactive unqualified fuel type which must be stored(e.g.4.75 w/o fresh fuel).

2) Calculate the amount of burnup required for the filler assembly, so that when grouped with the high reactivity fuel assemblies, the net reactivity meets the rack reactivity qualifications. This is done by performing multiple SIMULATE runs with increasing amounts of burnup on the filler assembly.[3]

12123) A linear regression on the reactivity values is performed for the combination of the high reactivity and filler fuel assemblies. As before, the regression equation is solved simultaneously with the rack maximum reactivity curve. The equation solutions are the data for the filler qualification curve.

The process can be followed multiple times to accommodate variable storage rack designs (i.e. two region pools) and variable storage configurations. All of the desired qualification curves are then plotted on the same chart to produce the final storage rack qualification curves. Figure B-3 on the following page illustrates a full set of qualification curves for a two-region storage pool utilizing unrestricted (100%) and restricted (use of filler assemblies) storage configurations in each region.

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3 SIMULATE is used to calculate the reactivity for a group of assemblies. The base model for the SIMULATE checkerboard calculations is a group of four assemblies and supporting rack elements. The geometry is infinitely reflected with periodic boundary conditions.

Figure B-3

Qualification Curve for Multiple Storage Configurations