Duke Power
A Duke Energy Company

Duke Power Company
A Duke Energy Company
McGuire Nuclear Station
MG01VP
12700 Hagers Ferry Rd.
Huntersville, NC 28078-9340

(704) 875-4800 OFFICE
(704) 875-4809 FAX

**H. B. Barron**
*Vice President, McGuire*
*Nuclear Generation Department*

April 18, 2002

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Duke Energy Corporation (DEC) McGuire Nuclear Station Units 1 and 2 Docket Nos. 50-369/50-370
Proposed Technical Specification (TS) Amendments TS 3.7.15 - Spent Fuel Assembly Storage, and TS 4.3 - Fuel Storage

Reference: DEC letter to NRC dated August 1, 2000

Pursuant to 10 CFR 50.90 and 10 CFR 50.4, this letter submits a license amendment request (LAR) for the McGuire Nuclear Station Facility Operating Licenses (FOL) and TSs. This amendment request is similar to a LAR previously submitted by letter dated August 1, 2000, which was approved by the NRC on November 27, 2000 (TAC NOS. MA9730 and MA9731). DEC met with the NRC in White Flint on December 11, 2001 and February 5, 2002 to address the Boraflex degradation issues, the basis for this LAR, and also DEC's corrective actions to improve the spent fuel storage issues at McGuire.

This LAR will change the McGuire TS 3.7.15 to provide revised spent fuel pool storage criteria, and revised fuel enrichment and burnup requirements which take credit for soluble boron in maintaining acceptable margins of subcriticality in the spent fuel storage pools. In addition, this LAR will increase the required soluble boron credit from 730 ppm boron to 850 ppm boron in McGuire TS 4.3.1 to provide revised criteria for acceptable levels of subcriticality in the McGuire spent fuel storage pools. This LAR also redefines certain boundary conditions between different loading patterns of fuel assemblies. These changes are necessary to reflect the reduction of credit for Boraflex from 50% to 40% in Region 2A of the spent fuel pool and to optimize spent fuel storage configurations in the pool. This proposed amendment is applicable to Facility Operating Licenses NPF-9 and NPF-17 for the McGuire Nuclear Station.

A001

Attachment 1 provides marked up pages of the existing McGuire TSs showing the proposed changes. Attachment 2 contains the new McGuire TS pages. The Description of Proposed Changes and Technical Justification is provided in Attachment 3. Pursuant to 10CFR50.92, Attachment 4 documents the determination that this proposed amendment contains no significant hazards considerations. Pursuant to 10CFR51.22 (c)(9), Attachment 5 provides the basis for the categorical exclusion from performing an Environmental Assessment or Impact Statement. The McGuire Spent Fuel Pool Criticality Analysis, and the McGuire Boraflex Degradation Analysis used to support this LAR are shown in Attachments 6 and 7, respectively. Also, please refer to Attachment 7 of the referenced letter for the supporting McGuire Spent Fuel Pool Dilution Analysis Summary used to support this LAR. Attachments 9 and 10 show the proposed and revised BASES for TS 3.7.14 and 3.7.15.

Implementation of this amendment to the McGuire FOLs and TSs will impact the station's UFSAR. Consequently, upon approval of this LAR, the applicable revisions will be included in a McGuire UFSAR update. These revisions will update Chapter 16 of the UFSAR, "Selected Licensee Commitments" as shown in Attachment 8. This commitment provides for periodic monitoring of future Boraflex degradation. If this monitoring determines that the Boraflex in a spent fuel storage pool has degraded to levels that would not support the conclusions of the McGuire Criticality Analysis that provides a basis for this LAR, then a future LAR would be submitted proposing additional changes to the McGuire TSs as needed to maintain acceptable levels of subcriticality in the McGuire spent fuel storage pools.

In accordance with Duke internal procedures and the Quality Assurance Program Topical Report, this proposed amendment has been previously reviewed and approved by the McGuire Station's Plant Operations Review Committee and the Duke Corporate Nuclear Safety Review Board. Pursuant to 10CFR50.91, a copy of this LAR is being forwarded to the appropriate North Carolina state officials.

In accordance with the current TSs, conservative predictions of boraflex degradation in the McGuire spent fuel pool will require numerous relocations of spent fuel assemblies prior to January 1, 2003. Consequently, DEC requests approval of this LAR by December 1, 2002 to minimize the number of relocations. As indicated in the attached "No Significant Hazards Consideration Evaluation", the proposed changes in this LAR will not result in a significant reduction in the facility's margin of safety.

not result in a significant reduction in the facility's margin of safety.

Please contact Norman T. Simms of Regulatory Compliance at 704-875-4685 with any questions regarding this LAR.

Very truly yours,

H B Barron

H. B. Barron

Attachments

xc: (w/attachments)

L.A. Reyes
Administrator, Region II
U.S. Nuclear Regulatory Commission
Atlanta Federal Center
61 Forsyth Street, SW, Suite 23T85
Atlanta, GA. 30303

S.M. Shaeffer
NRC Senior Resident Inspector
McGuire Nuclear Station

R.E. Martin, Project Manager (addressee only)
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
One White Flint North, Mail Stop O-8G9
11555 Rockville Pike
Rockville, MD 20852-2738

R.M. Fry, Director
Division of Radiation Protection
State of North Carolina
3825 Barrett Drive
Raleigh, N.C. 27609-7221

H. B. Barron, being duly sworn, states that he is Vice President of McGuire Nuclear Station; that he is authorized on the part of Duke Energy Corporation to sign and file with the U.S. Nuclear Regulatory Commission these revisions to the McGuire Nuclear Station Facility Operating Licenses Nos. NPF-9 and NPF-17; and, that all statements and matters set forth therein are true and correct to the best of his knowledge.

H B Barron

H. B. Barron, Vice President
McGuire Nuclear Station
Duke Energy Corporation

Subscribed and sworn to before me on April 18, 2002.

Deborah G. Threap

Notary Public
Deborah G. Threp

My Commission Expires: 4/6/2007

bxc: (w. attachments)

T.C. Geer (MG05EE)
K.L. Crane (MG01RC)
G.D. Gilbert (CN01RC)
G.B. Swindlehurst (EC08H)
L.E. Nicholson (ON03RC)
T.M. Luniewski (MG05EE)
S.C. Ballard (MG05EE)
D.C. Jones (EC08F)
C.J. Thomas (MG01RC)
N.T. Simms (MG01RC)
ELL (EC05O)
NSRB Support Staff (EC05N)
Masterfile 1.3.2.9

# ATTACHMENT 1

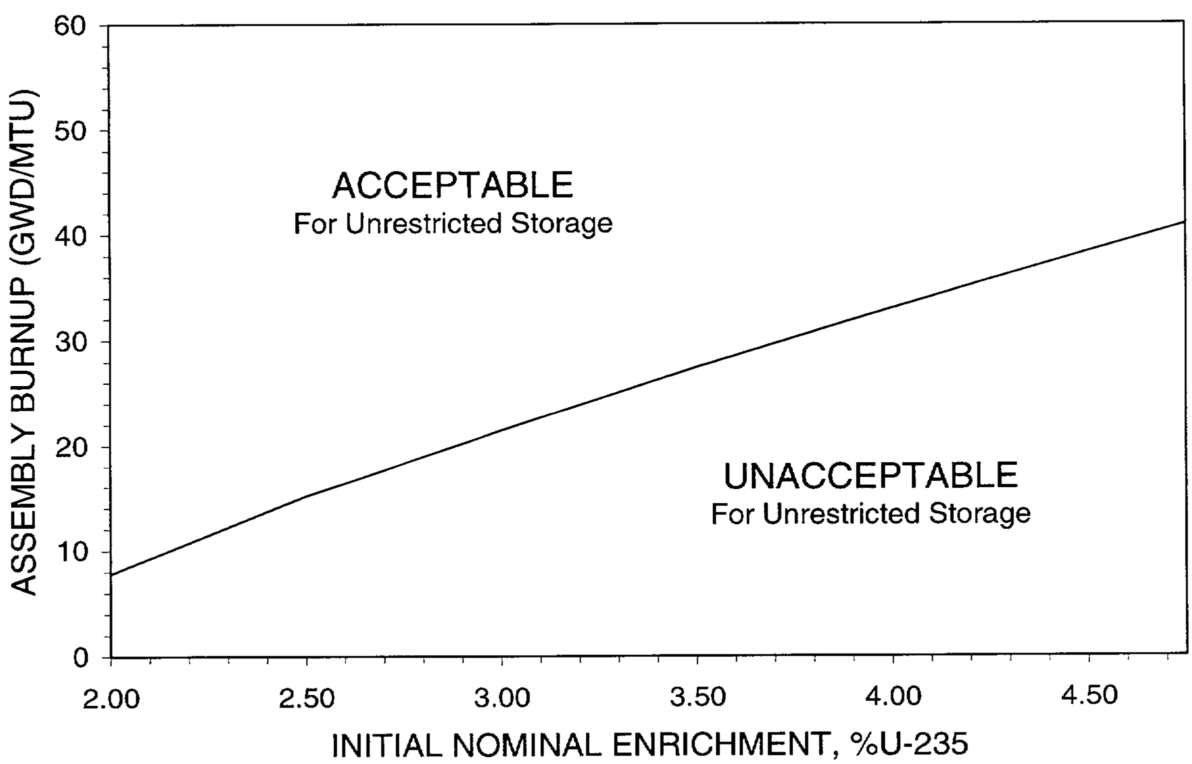
# PROPOSED REVISIONS TO THE MCGUIRE TECHNICAL SPECIFICATIONS

REPLACE
WITH NEXT
PAGE



Table 3.7.15-7 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 2A Storage

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.61 (or less) | 0 |
| 2.00 | 7.79 |
| 2.50 | 15.14 |
| 3.00 | 21.45 |
| 3.50 | 27.42 |
| 4.00 | 33.00 |
| 4.50 | 38.32 |
| 4.75 | 40.91 |




NOTES:

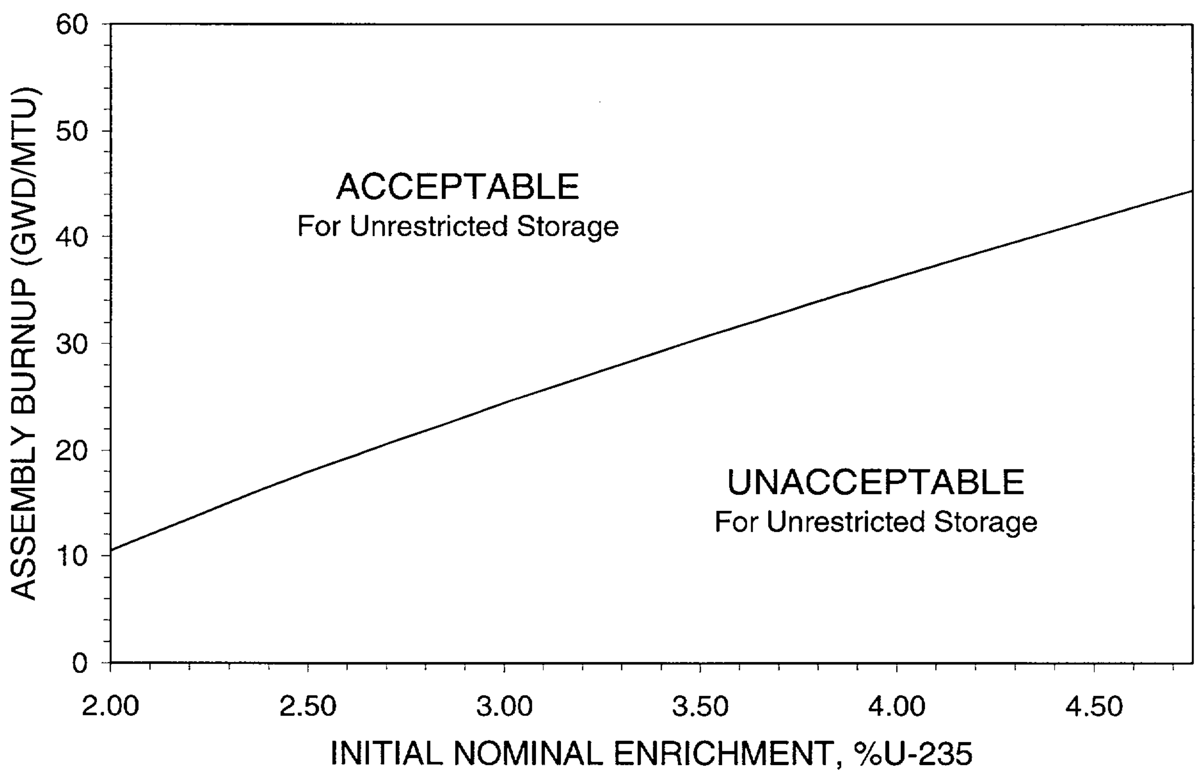
Fuel which differs from those designs used to determine the requirements of Table 3.7.15-7 may be qualified for Unrestricted Region 2A storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

NEW PAGE
3.7.15-9



Table 3.7.15-7 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 2A Storage

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.50 (or less) | 0.00 |
| 2.00 | 10.50 |
| 2.50 | 17.97 |
| 3.00 | 24.49 |
| 3.50 | 30.55 |
| 4.00 | 36.25 |
| 4.50 | 41.71 |
| 4.75 | 44.39 |




NOTES:

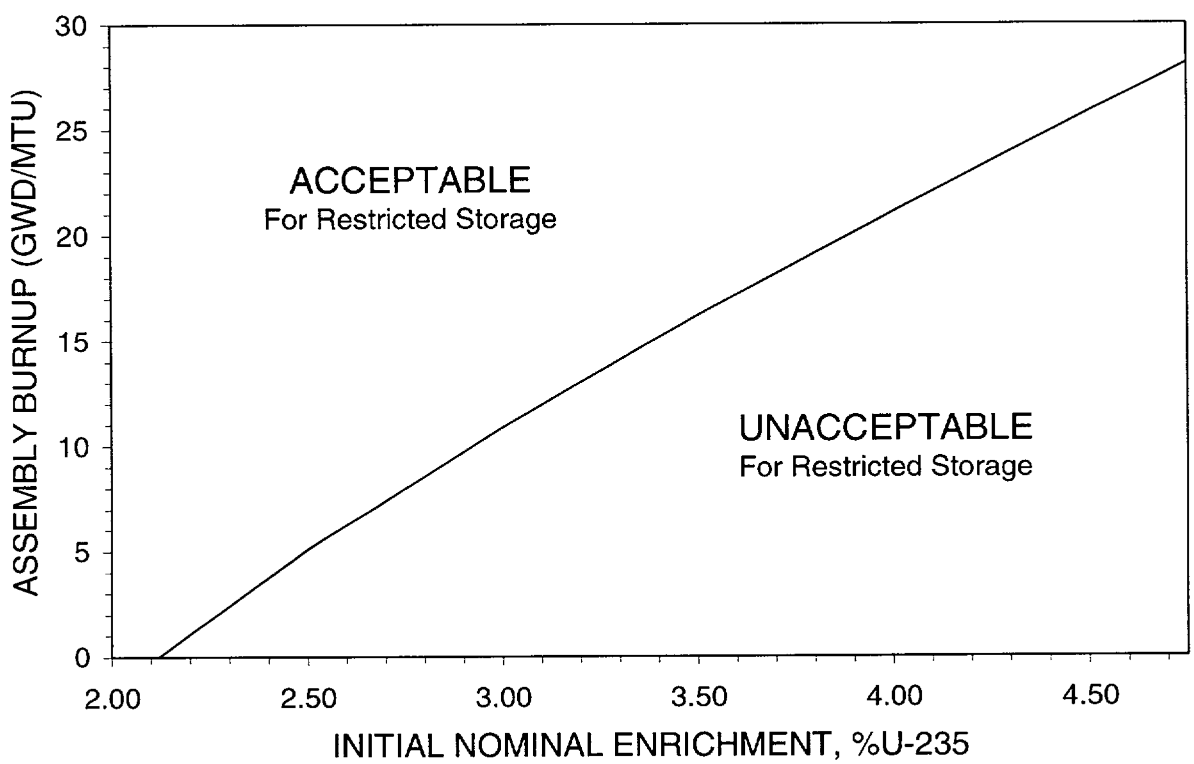
Fuel which differs from those designs used to determine the requirements of Table 3.7.15-7 may be qualified for Unrestricted Region 2A storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

REPLACE
WITH NEXT
PAGE



Table 3.7.15-8 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Restricted Region 2A Storage with Fillers

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 2.12 (or less) | 0 |
| 2.50 | 5.10 |
| 3.00 | 10.88 |
| 3.50 | 16.19 |
| 4.00 | 21.07 |
| 4.50 | 25.81 |
| 4.75 | 28.11 |




NOTES:

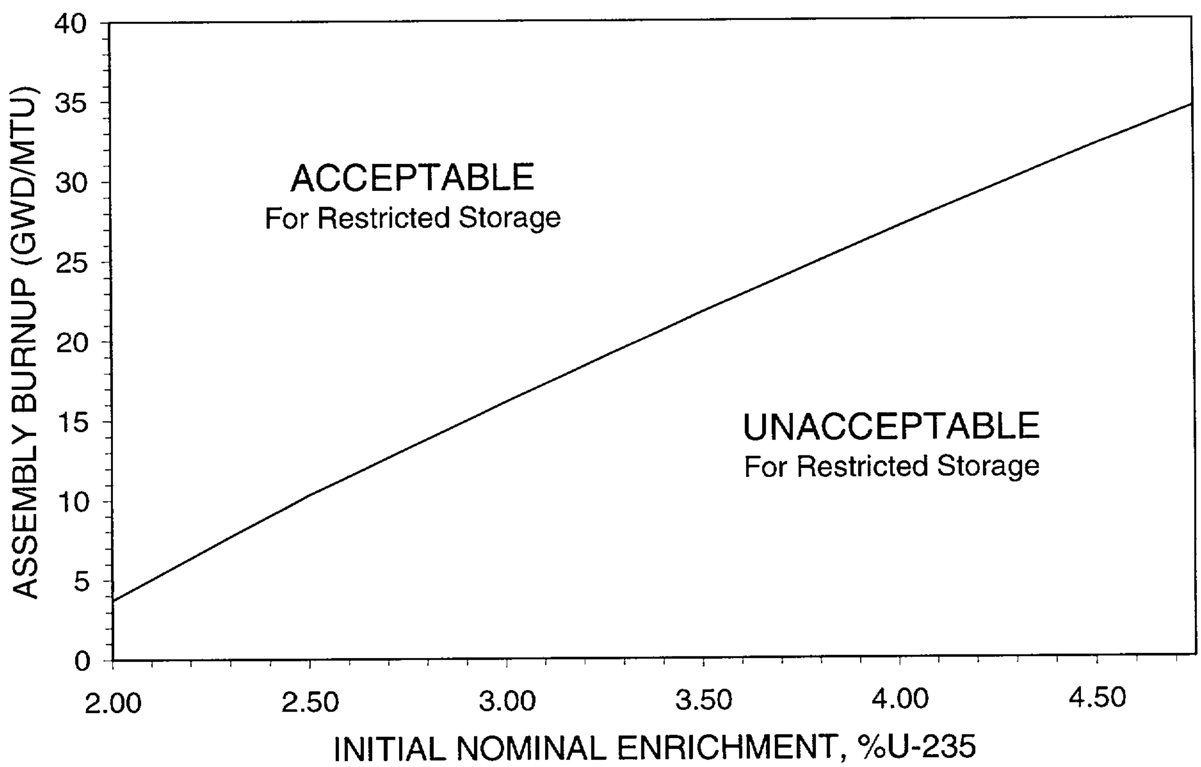
Fuel which differs from those designs used to determine the requirements of Table 3.7.15-8 may be qualified for Restricted Region 2A Storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

NEW PAGE
3.7.15-10



Table 3.7.15-8 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Restricted Region 2A Storage with Fillers

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.80 (or less) | 0.00 |
| 2.00 | 3.70 |
| 2.50 | 10.30 |
| 3.00 | 16.10 |
| 3.50 | 21.70 |
| 4.00 | 27.00 |
| 4.50 | 32.10 |
| 4.75 | 34.50 |




NOTES:

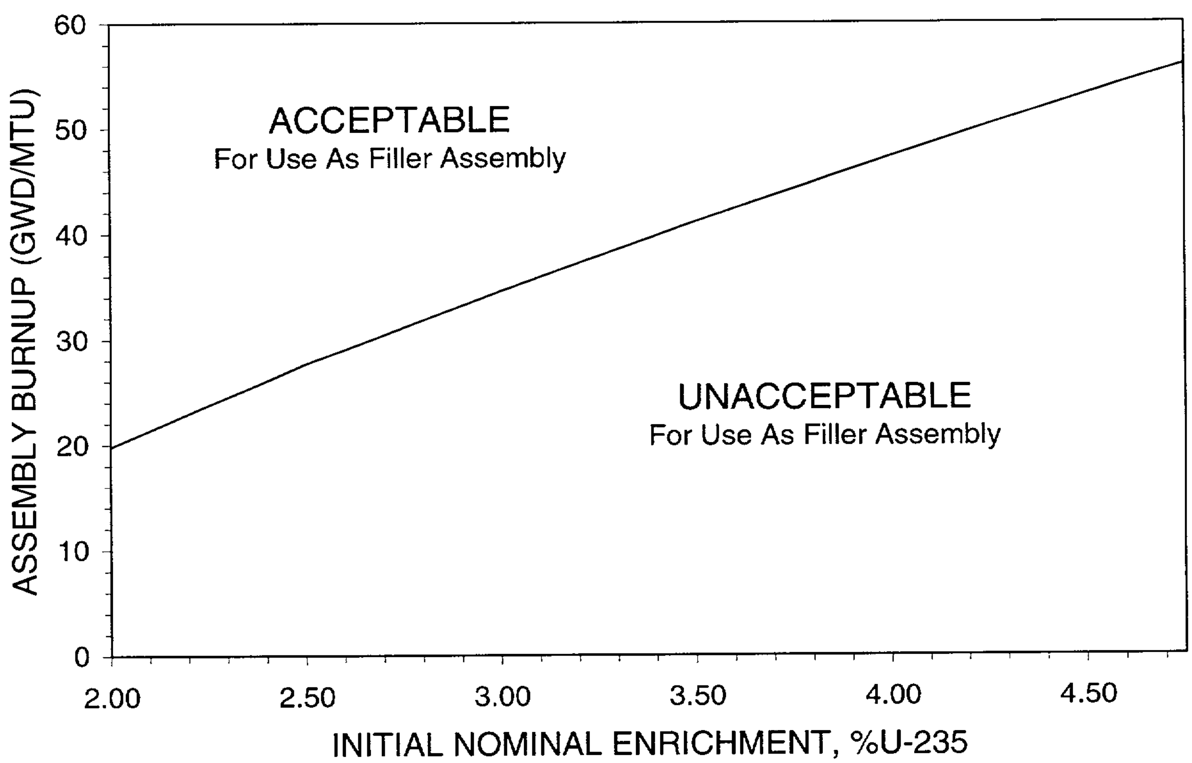
Fuel which differs from those designs used to determine the requirements of Table 3.7.15-8 may be qualified for Restricted Region 2A Storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

REPLACE WITH NEXT PAGE



Table 3.7.15-9 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Region 2A Filler Assemblies

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.20 (or less) | 0 |
| 2.00 | 19.80 |
| 2.50 | 27.64 |
| 3.00 | 34.56 |
| 3.50 | 41.08 |
| 4.00 | 47.25 |
| 4.50 | 53.15 |
| 4.75 | 56.01 |




NOTES:

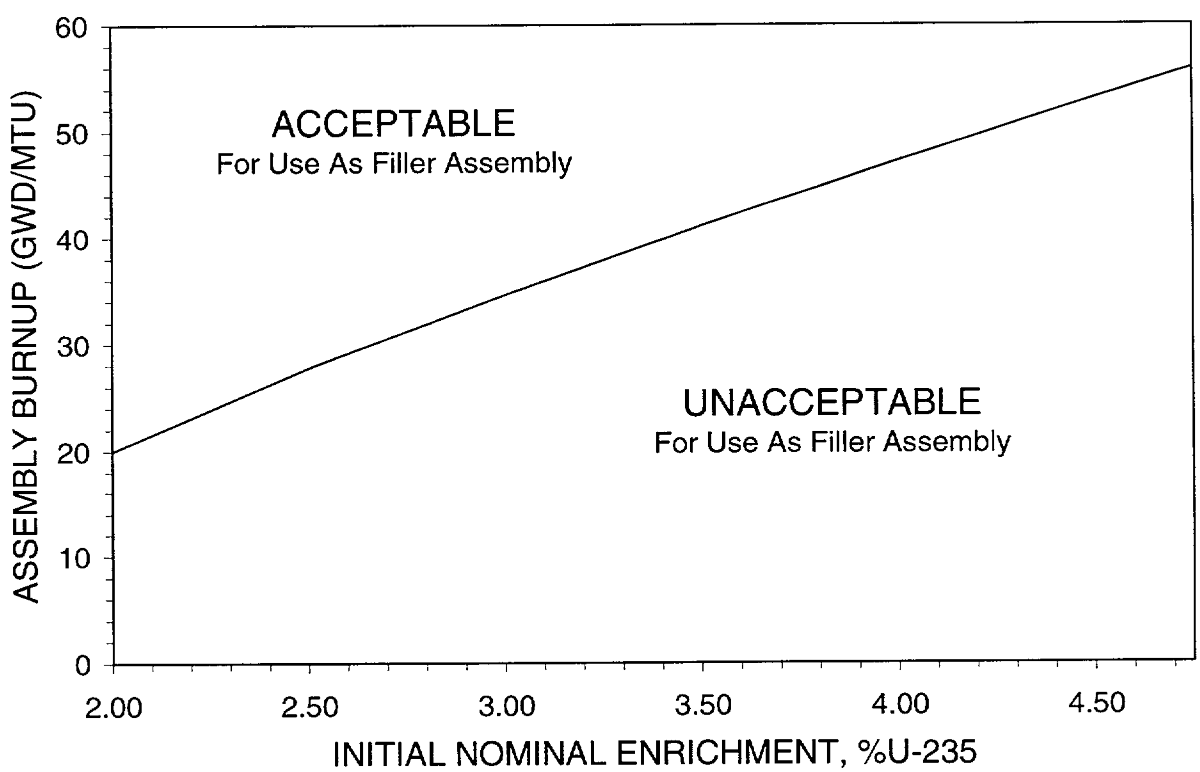
Fuel which differs from those designs used to determine the requirements of Table 3.7.15-9 may be qualified for use as a Region 2A Filler Assembly by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

NEW PAGE
3.7.15-11



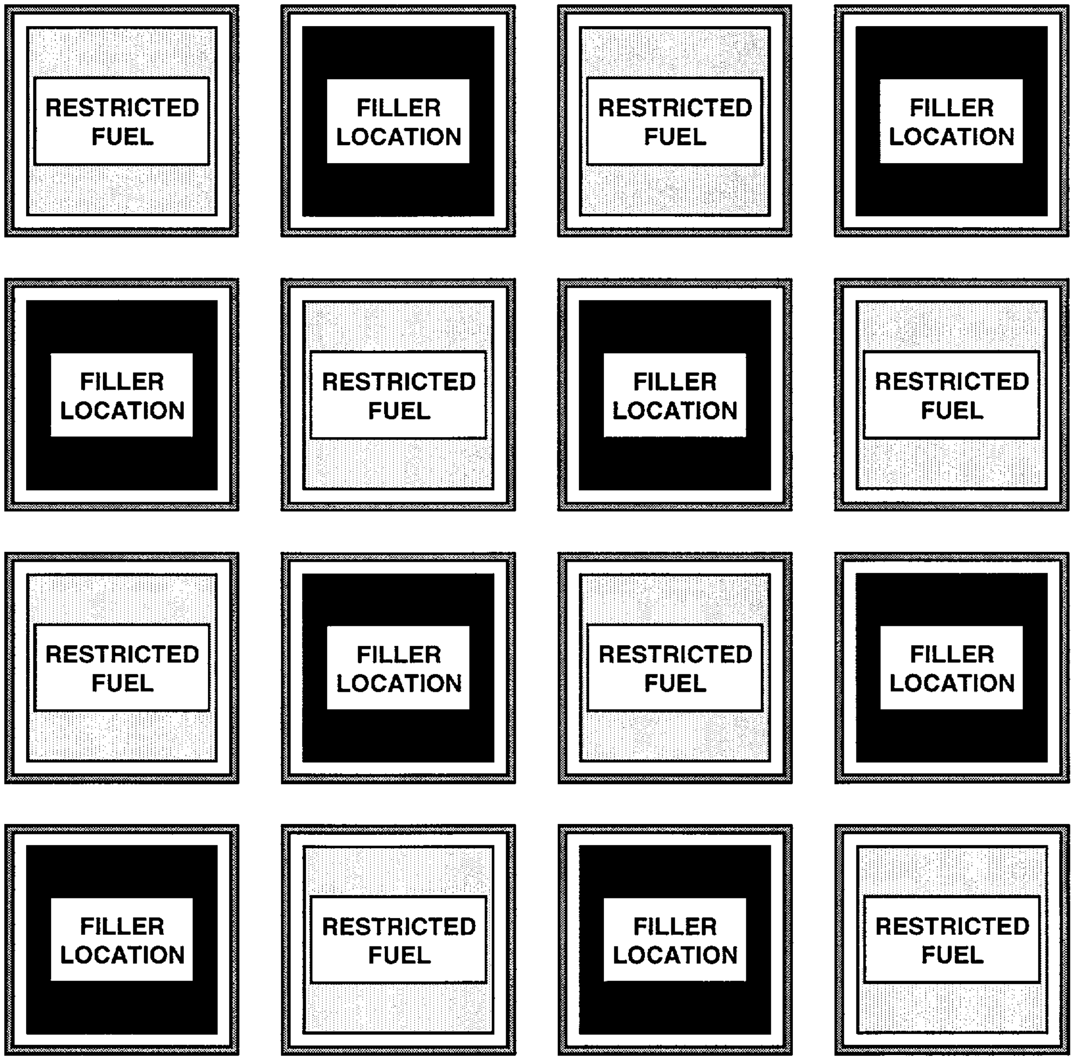
Table 3.7.15-9 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Region 2A Filler Assemblies

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.15 (or less) | 0.00 |
| 2.00 | 20.00 |
| 2.50 | 27.80 |
| 3.00 | 34.60 |
| 3.50 | 41.10 |
| 4.00 | 47.20 |
| 4.50 | 53.10 |
| 4.75 | 55.90 |



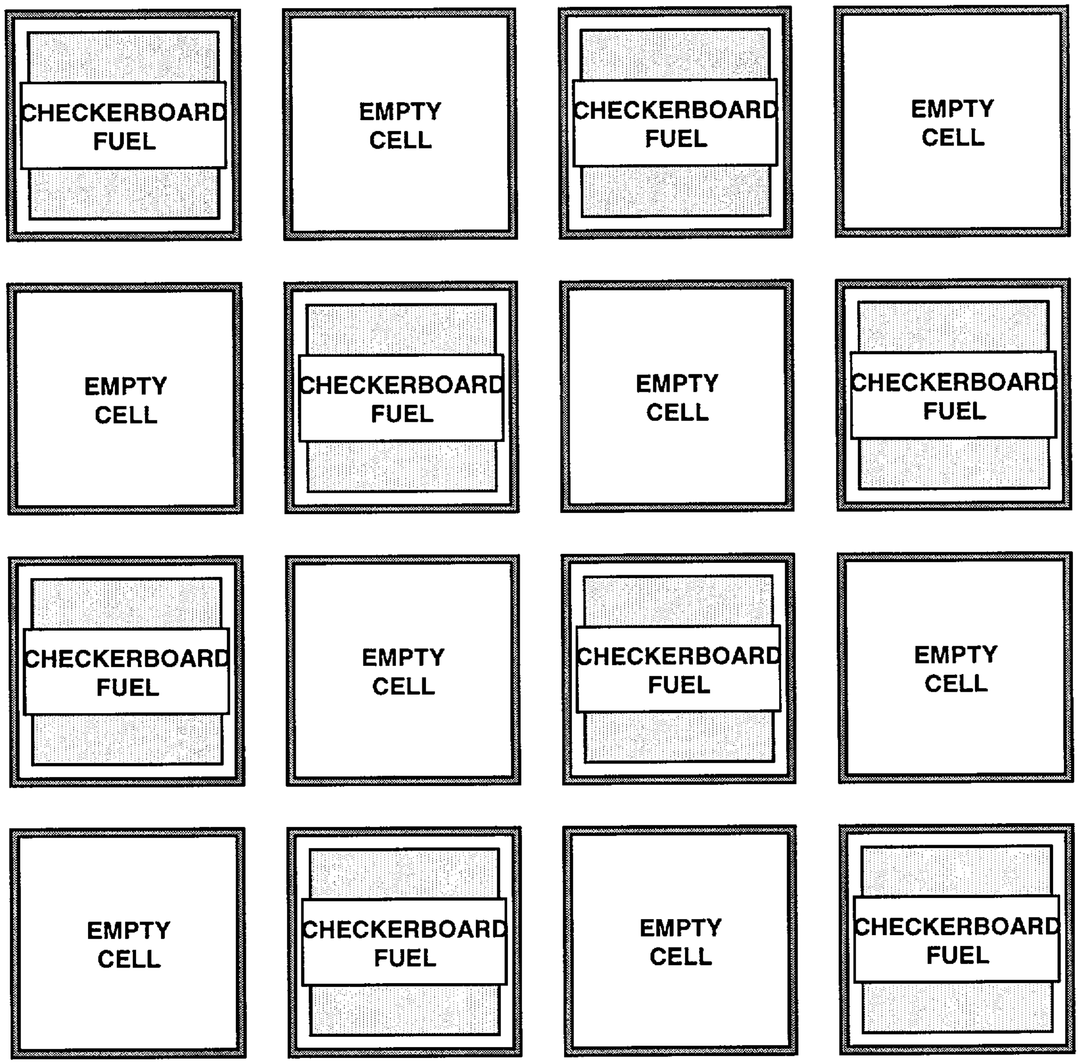

NOTES:

Fuel which differs from those designs used to determine the requirements of Table 3.7.15-9 may be qualified for use as a Region 2A Filler Assembly by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.




| | |
|---|---|
| Restricted Fuel: | Fuel which meets the minimum burnup requirements of Table 3.7.15-5, or non-fuel components, or an empty location. |
| Filler Location: | Either fuel which meets the minimum burnup requirements of Table 3.7.15-6, or an empty cell. |
| Boundary Condition: | ~~No restrictions on boundary assemblies.~~ Any Restricted Region 1B Storage Area must be separated from any other storage area by at least one row of 1B Filler Locations or empty cells, at all boundaries between storage regions. |

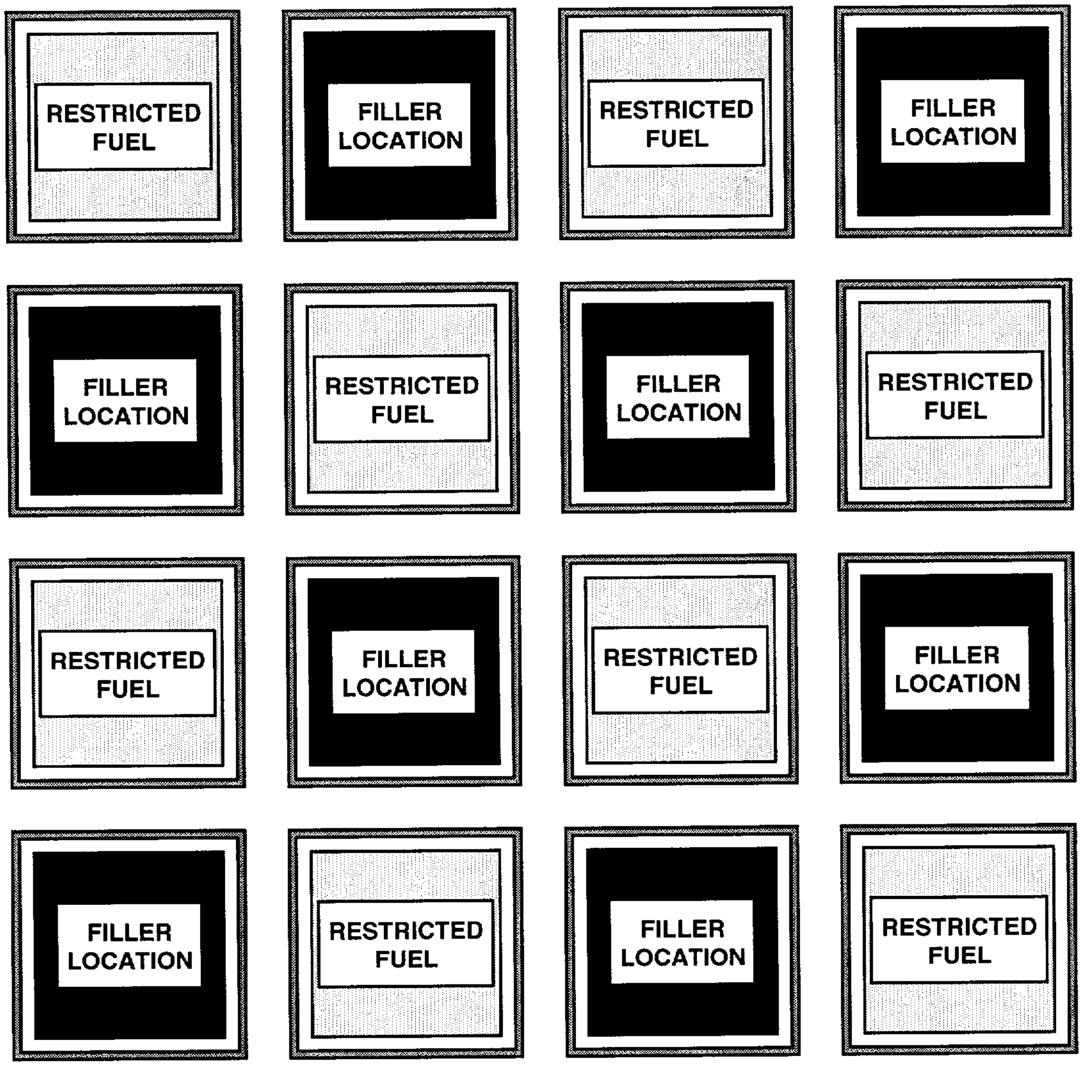
Figure 3.7.15-2 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Restricted Region 1B Storage




Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.7.15-5. (Fuel which does meet the requirements of Table 3.7.15-5, or non-fuel components, or an empty location may be placed in checkerboard fuel locations as ~~needed~~)

Boundary Condition: ~~No restrictions on boundary assemblies.~~ Any Checkerboard Region 1B Storage Area must be separated from any other storage area by at least one row of empty cells, at all boundaries between ~~storage regions.~~

Figure 3.7.15-3 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Checkerboard Region 1B Storage

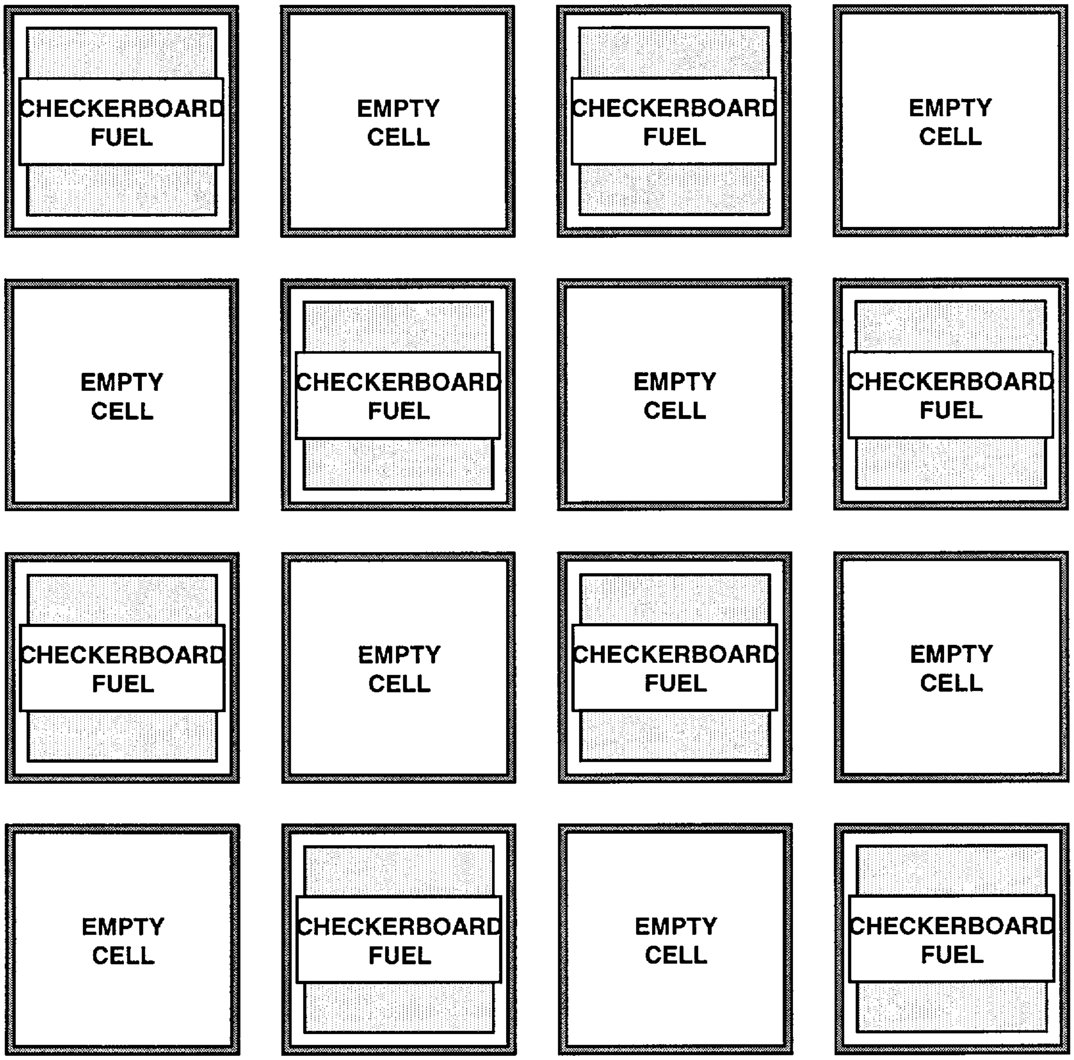



Restricted Fuel: Fuel which meets the minimum burnup requirements of Table 3.7.15-8, or non-fuel components, or an empty location.

Filler Location: Either fuel which meets the minimum burnup requirements of Table 3.7.15-9, or an empty cell.

Boundary Condition: ~~No restrictions on boundary assemblies.~~ At least three of the four faces of each 2A Restricted Fuel assembly must be adjacent to a 2A Filler Location, an empty cell, or the pool wall, at all boundaries between storage regions.

Figure 3.7.15-4 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Restricted Region 2A Storage




Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.7.15-8. (Fuel which does meet the requirements of Table 3.7.15-8, or non-fuel components, or an empty location may be placed in checkerboard fuel locations as ~~needed~~)

Boundary Condition: ~~No Restrictions on boundary assemblies.~~ At least three of the four faces of each Checkerboard Fuel assembly must be adjacent to an empty cell or the pool wall, at all boundaries between storage regions.

Figure 3.7.15-5 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Checkerboard Region 2A Storage

# 4.0 DESIGN FEATURES

## 4.1 Site Location

The McGuire Nuclear Station site is located at latitude 35 degrees, 25 minutes, 59 seconds north and longitude 80 degrees, 56 minutes, 55 seconds west. The Universal Transverse Mercator Grid Coordinates are E 504, 669, 256, and N 3, 920, 870, 471. The site is in northwestern Mecklenburg County, North Carolina, 17 miles north-northwest of Charlotte, North Carolina.

## 4.2 Reactor Core

### 4.2.1 Fuel Assemblies

The reactor shall contain 193 fuel assemblies. Each assembly shall consist of a matrix of Zircalloy fuel rods with an initial composition of natural or slightly enriched uranium dioxide ($UO_2$) as fuel material. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all fuel safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

### 4.2.2 Control Rod Assemblies

The reactor core shall contain 53 control rod assemblies. The control material shall be silver indium cadmium (Unit 1) silver indium cadmium and boron carbide (Unit 2) as approved by the NRC.

## 4.3 Fuel Storage

### 4.3.1 Criticality

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

a. Fuel assemblies having a maximum nominal U-235 enrichment of 4.75 weight percent;

b. $k_{eff} < 1.0$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

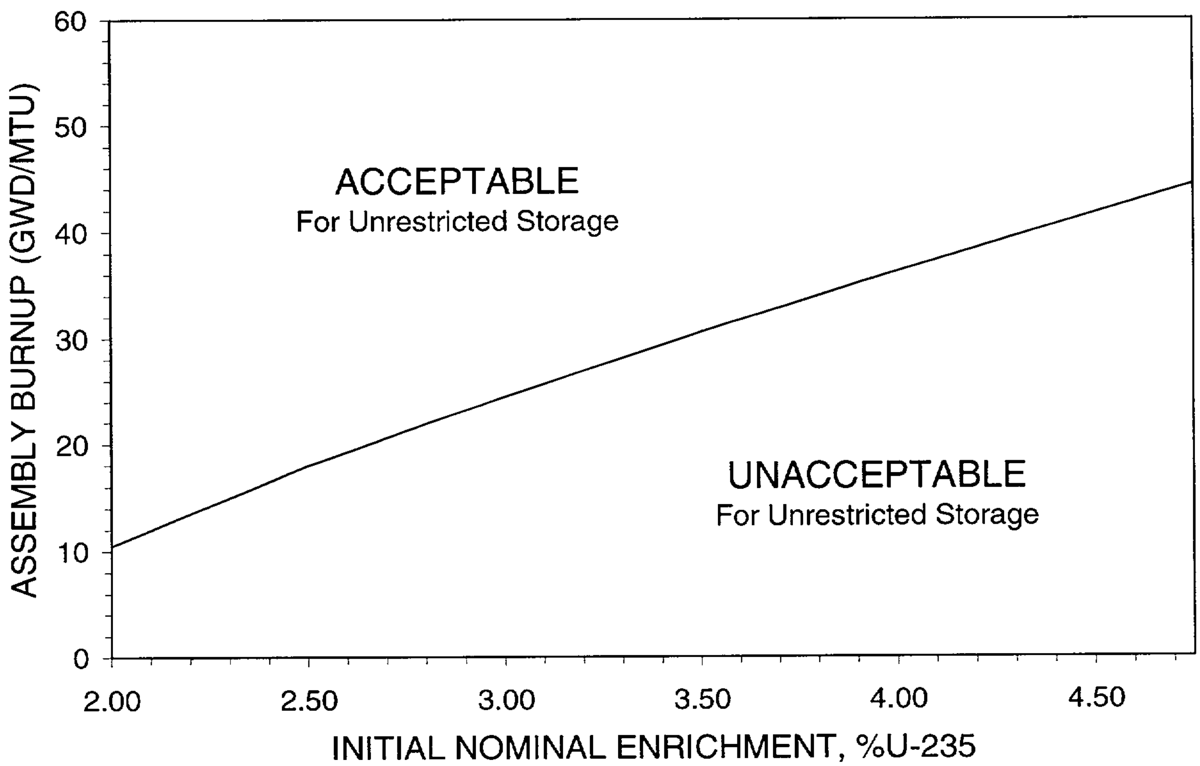
c. $k_{eff} \leq 0.95$ if fully flooded with water borated to ~~730~~ 850 ppm, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

# ATTACHMENT 2

# REVISED MCGUIRE TECHNICAL SPECIFICATIONS

Table 3.7.15-7 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Unrestricted Region 2A Storage

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.50 (or less) | 0.00 |
| 2.00 | 10.50 |
| 2.50 | 17.97 |
| 3.00 | 24.49 |
| 3.50 | 30.55 |
| 4.00 | 36.25 |
| 4.50 | 41.71 |
| 4.75 | 44.39 |

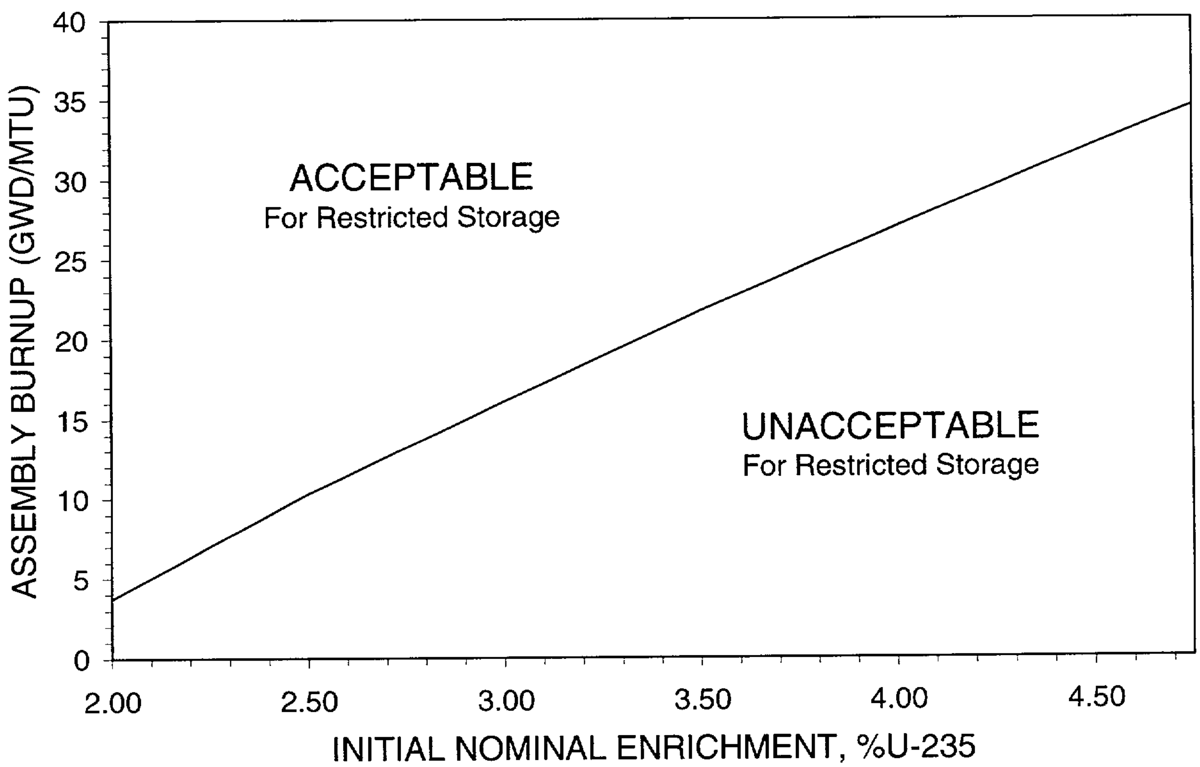



NOTES:

Fuel which differs from those designs used to determine the requirements of Table 3.7.15-7 may be qualified for Unrestricted Region 2A storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

Table 3.7.15-8 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Restricted Region 2A Storage with Fillers

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.80 (or less) | 0.00 |
| 2.00 | 3.70 |
| 2.50 | 10.30 |
| 3.00 | 16.10 |
| 3.50 | 21.70 |
| 4.00 | 27.00 |
| 4.50 | 32.10 |
| 4.75 | 34.50 |

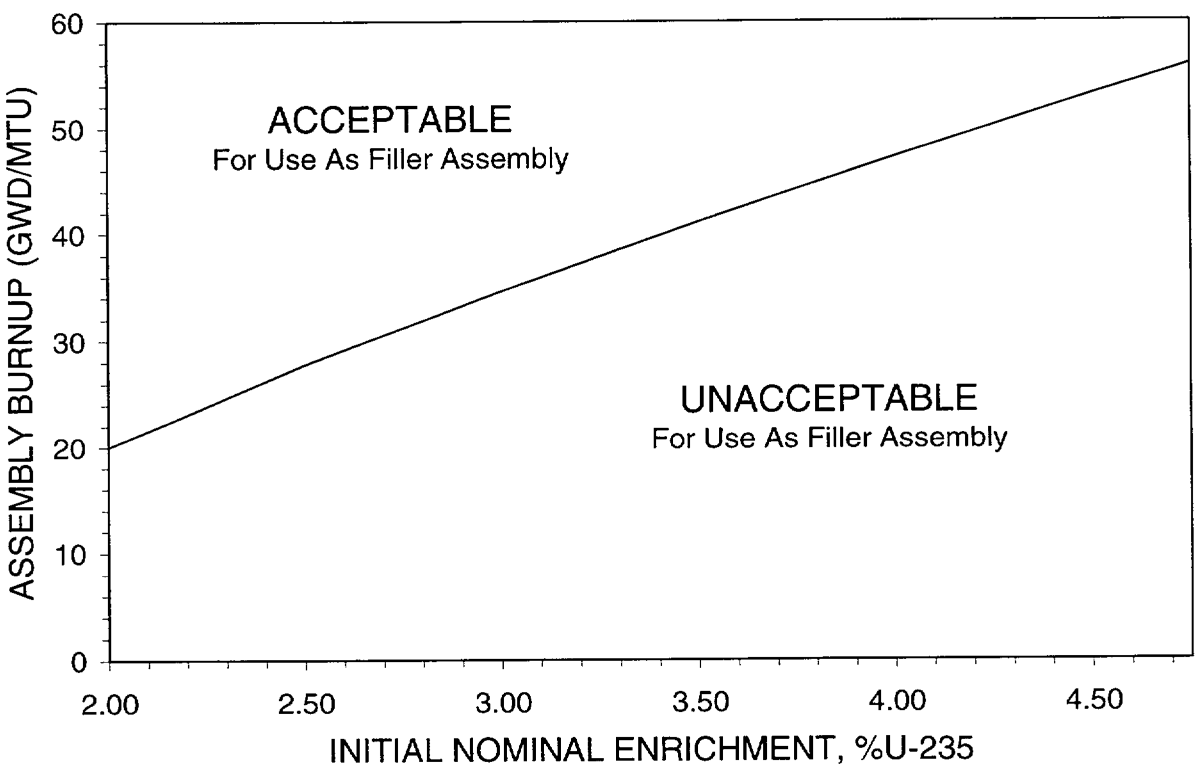



NOTES:

Fuel which differs from those designs used to determine the requirements of Table 3.7.15-8 may be qualified for Restricted Region 2A Storage by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

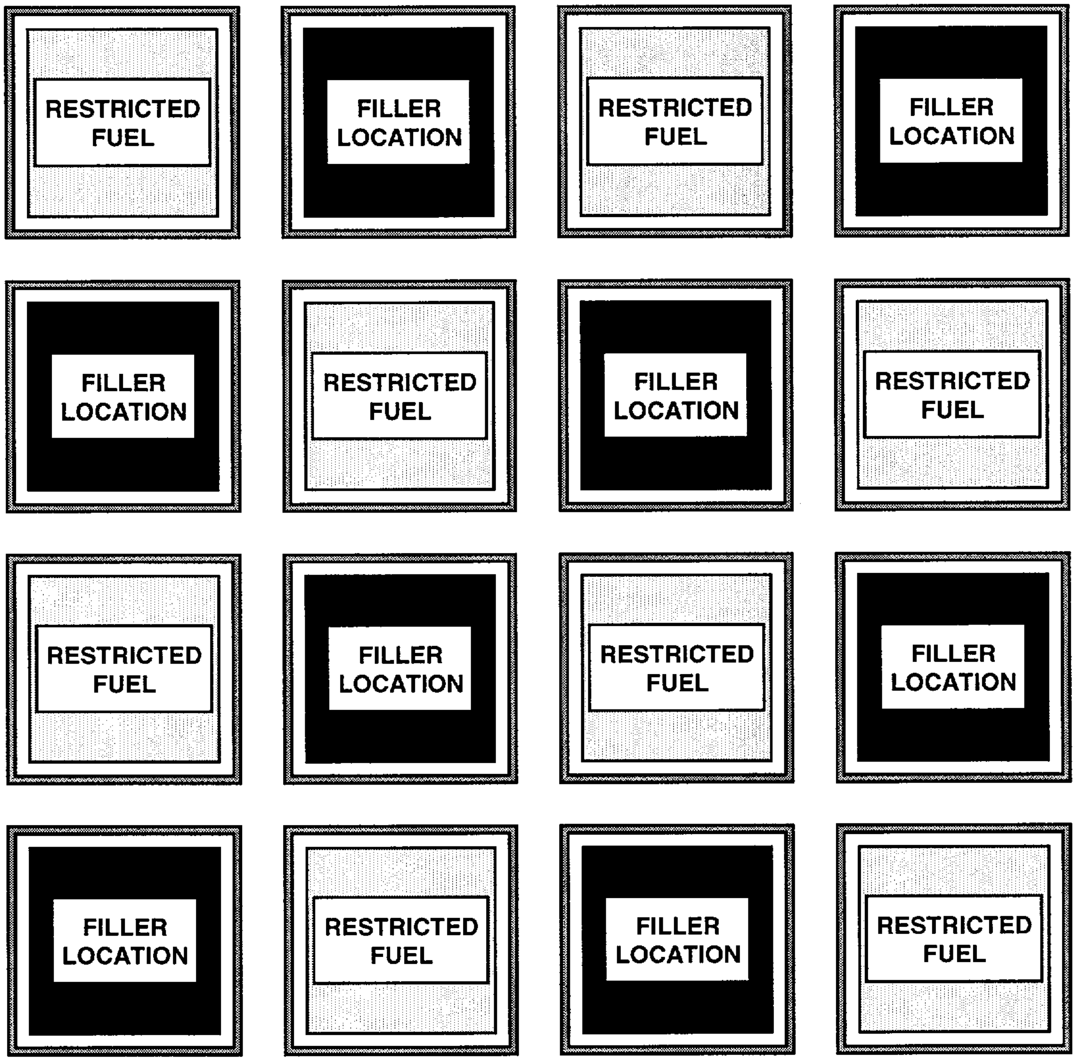
Table 3.7.15-9 (page 1 of 1)
Minimum Qualifying Burnup Versus Initial Enrichment
for Region 2A Filler Assemblies

| Initial Nominal Enrichment (% U-235) | Assembly Burnup (GWD/MTU) |
|---|---|
| 1.15 (or less) | 0.00 |
| 2.00 | 20.00 |
| 2.50 | 27.80 |
| 3.00 | 34.60 |
| 3.50 | 41.10 |
| 4.00 | 47.20 |
| 4.50 | 53.10 |
| 4.75 | 55.90 |




NOTES:

Fuel which differs from those designs used to determine the requirements of Table 3.7.15-9 may be qualified for use as a Region 2A Filler Assembly by means of an analysis using NRC approved methodology to assure that $k_{eff}$ is less than 1.0 with no boron and less than or equal to 0.95 with credit for soluble boron.

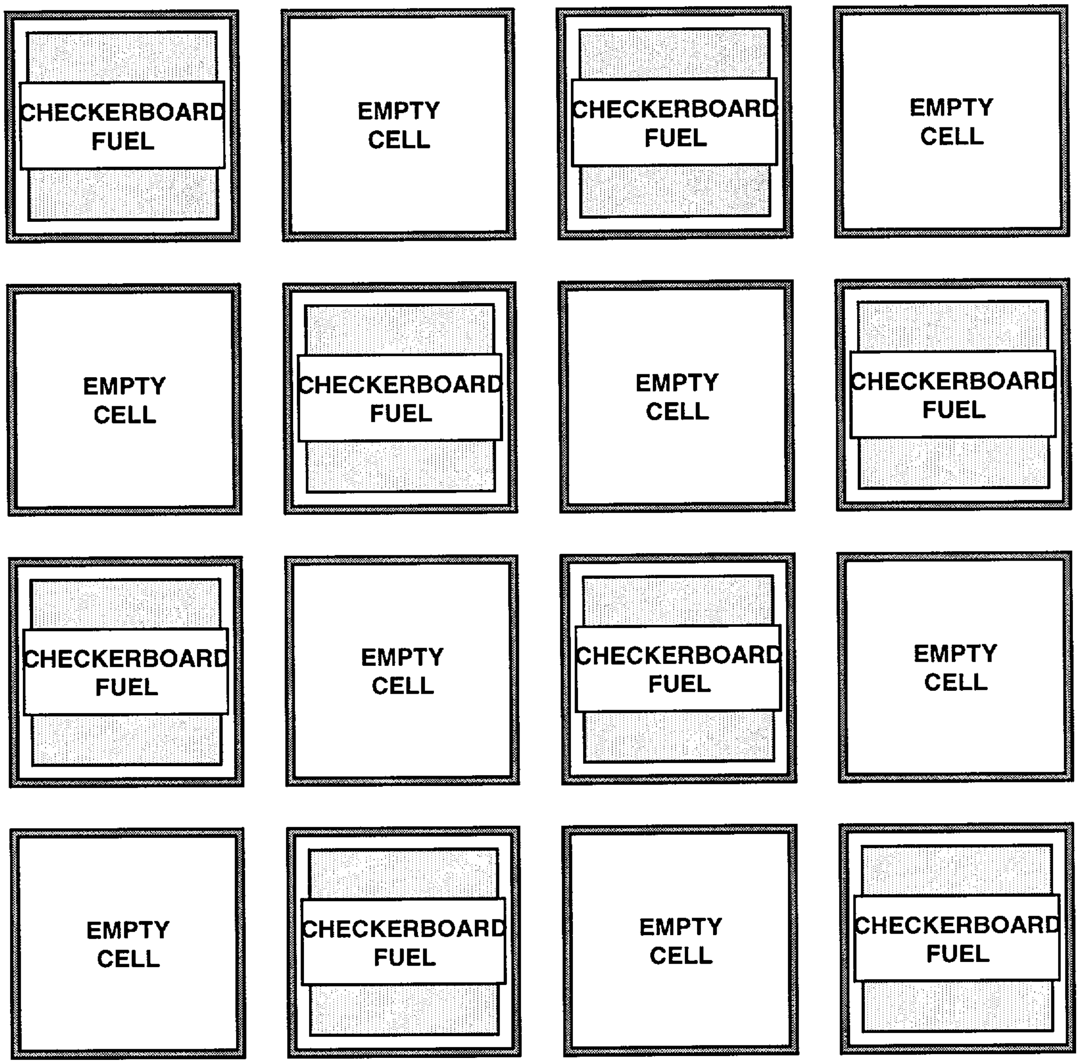



Restricted Fuel: Fuel which meets the minimum burnup requirements of Table 3.7.15-5, or non-fuel components, or an empty location.

Filler Location: Either fuel which meets the minimum burnup requirements of Table 3.7.15-6, or an empty cell.

Boundary Condition: Any Restricted Region 1B Storage Area must be separated from any other storage area by at least one row of 1B Filler Locations or empty cells, at all boundaries between storage regions.

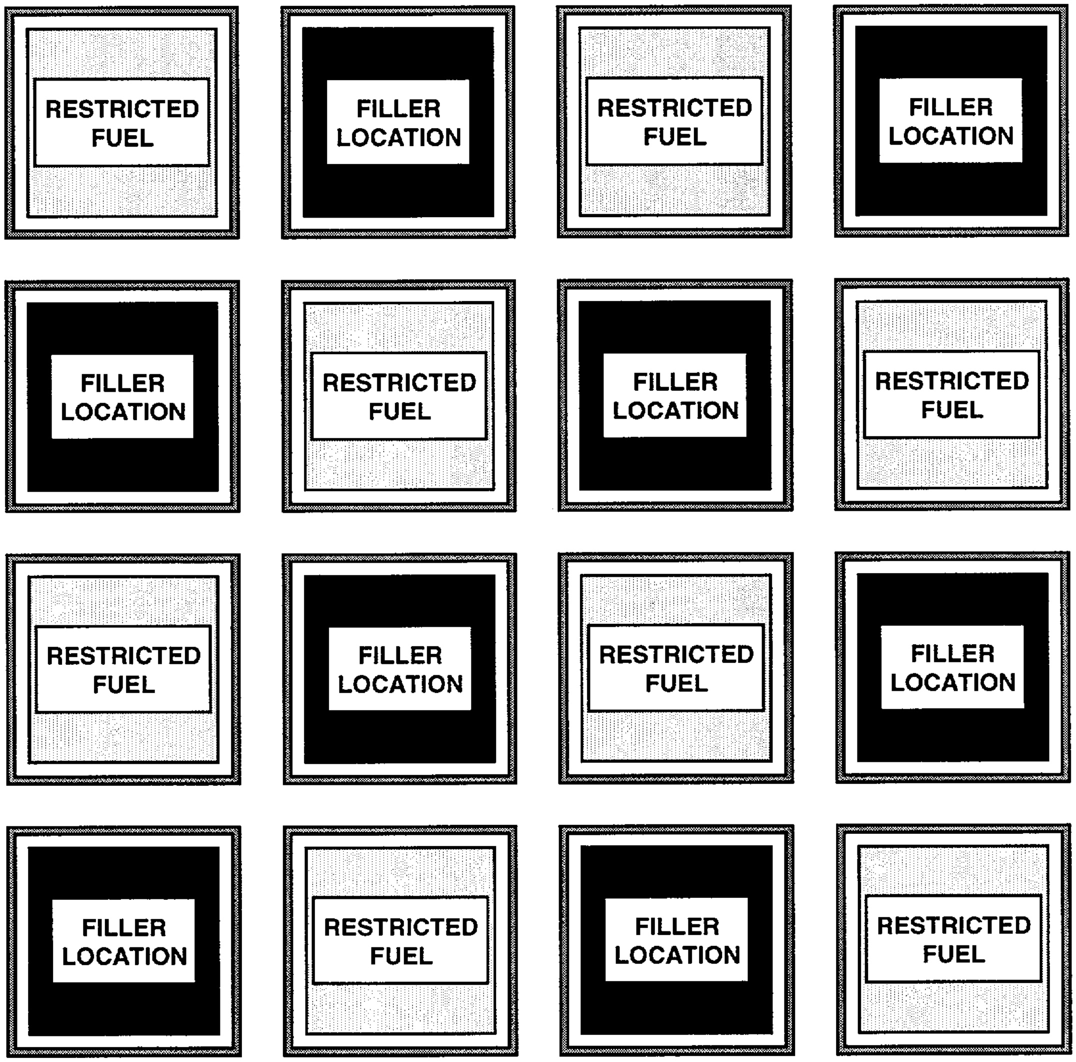
Figure 3.7.15-2 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Restricted Region 1B Storage




Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.7.15-5. (Fuel which does meet the requirements of Table 3.7.15-5, or non-fuel components, or an empty location may be placed in checkerboard fuel locations as needed)

Boundary Condition: Any Checkerboard Region 1B Storage Area must be separated from any other storage area by at least one row of empty cells, at all boundaries between storage regions.

Figure 3.7.15-3 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Checkerboard Region 1B Storage

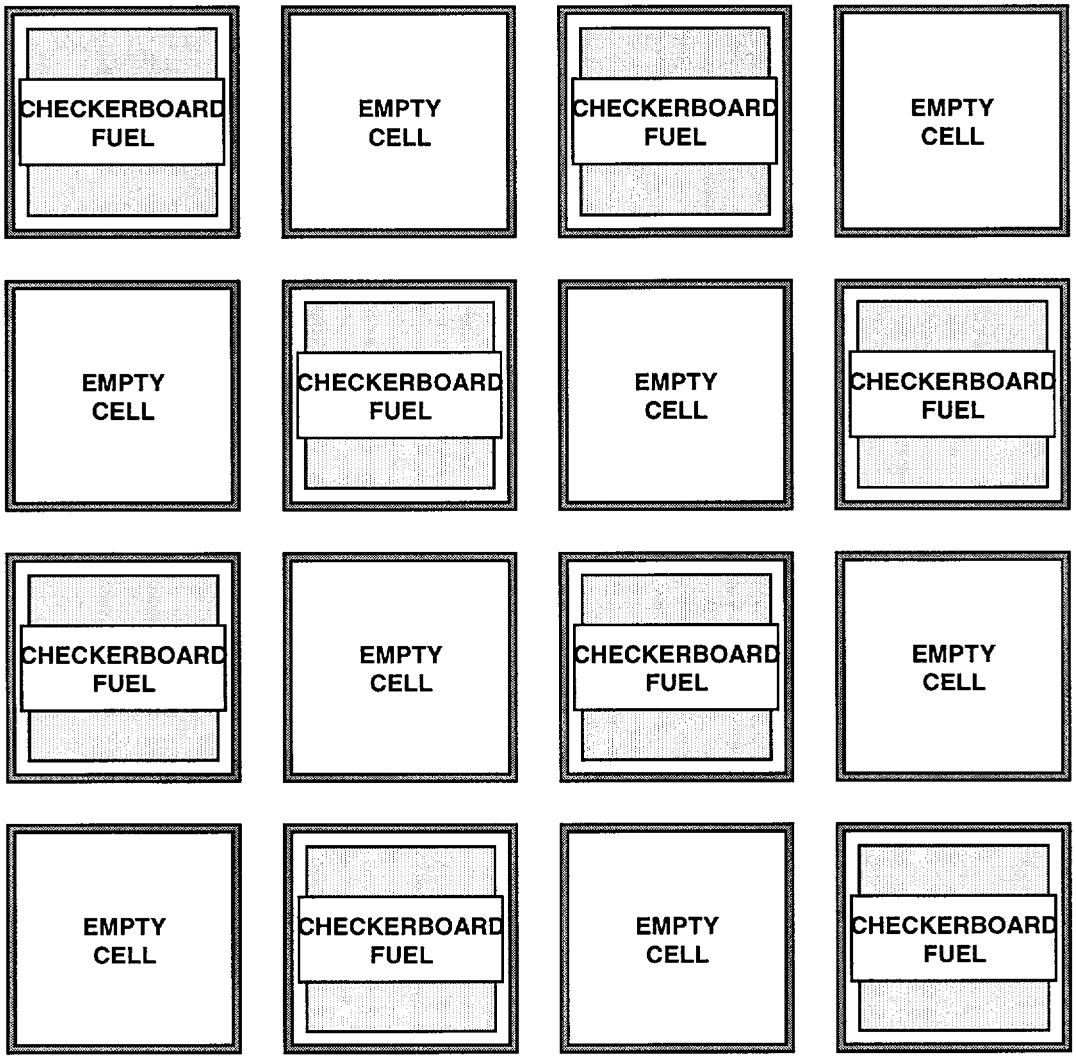



Restricted Fuel: Fuel which meets the minimum burnup requirements of Table 3.7.15-8, or non-fuel components, or an empty location.

Filler Location: Either fuel which meets the minimum burnup requirements of Table 3.7.15-9, or an empty cell.

Boundary Condition: At least three of the four faces of each 2A Restricted Fuel Assembly must be adjacent to a 2A Filler Location, an empty cell, or the pool wall, at all boundaries between storage regions.

Figure 3.7.15-4 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Restricted Region 2A Storage




Checkerboard Fuel: Fuel which does not meet the minimum burnup requirements of Table 3.7.15-8. (Fuel which does meet the requirements of Table 3.7.15-8, or non-fuel components, or an empty location may be placed in checkerboard fuel locations as needed)

Boundary Condition: At least three of the four faces of each Checkerboard Fuel Assembly must be adjacent to an empty cell, at all boundaries between storage regions.

Figure 3.7.15-5 (page 1 of 1)
Required 2 out of 4 Loading Pattern for Checkerboard Region 2A Storage

# 4.0 DESIGN FEATURES

## 4.1 Site Location

The McGuire Nuclear Station site is located at latitude 35 degrees, 25 minutes, 59 seconds north and longitude 80 degrees, 56 minutes, 55 seconds west. The Universal Transverse Mercator Grid Coordinates are E 504, 669, 256, and N 3, 920, 870, 471. The site is in northwestern Mecklenburg County, North Carolina, 17 miles north-northwest of Charlotte, North Carolina.

## 4.2 Reactor Core

### 4.2.1 Fuel Assemblies

The reactor shall contain 193 fuel assemblies. Each assembly shall consist of a matrix of Zircalloy fuel rods with an initial composition of natural or slightly enriched uranium dioxide ($UO_2$) as fuel material. Limited substitutions of zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all fuel safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

### 4.2.2 Control Rod Assemblies

The reactor core shall contain 53 control rod assemblies. The control material shall be silver indium cadmium (Unit 1) silver indium cadmium and boron carbide (Unit 2) as approved by the NRC.

## 4.3 Fuel Storage

### 4.3.1 Criticality

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

a. Fuel assemblies having a maximum nominal U-235 enrichment of 4.75 weight percent;

b. $k_{eff} < 1.0$ if fully flooded with unborated water, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

c. $k_{eff} \leq 0.95$ if fully flooded with water borated to 850 ppm, which includes an allowance for uncertainties as described in Section 9.1 of the UFSAR;

# ATTACHMENT 3

# DESCRIPTION OF PROPOSED CHANGES AND TECHNICAL JUSTIFICATION

Description of Proposed Changes

This LAR proposes a redefinition of McGuire spent fuel pool Region 2A storage, and a revision to the minimum burnup requirements for fuel assemblies stored in Region 2A. The proposed changes are described below and are based upon the reduction of the threshold amount of material in the McGuire Region 2A storage rack Boraflex panels from 50% of design minimum thickness to 40%. This threshold is being reduced to allow continued storage efficiency in Region 2 of the McGuire spent fuel pools, as a long-term solution to the Boraflex degradation issue is pursued. The evaluation of the criticality implications of this Boraflex reduction in Region 2A is documented in the revised McGuire Spent Fuel Pool Criticality Analysis (Attachment 6). The TS changes in this LAR include the following:

1. McGuire TS 4.3.1 will be revised to increase the boron concentration required to maintain $k_{eff} \leq 0.95$ from 730 ppm to 850 ppm. This increase in the boron credit requirements results from taking reactivity biases and uncertainties developed for the previous Region 2A 50% Boraflex model, and applying many of those biases and uncertainties to the new Region 2A 40% Boraflex model where convenient. This is a conservative measure, since the boron credit reactivity biases and uncertainties used in this manner increase with increasing Boraflex quantity. Note that the 850 ppm boron credit remains well below the 937 ppm boron remaining following a worst-case credible dilution event in the McGuire spent fuel pool (Attachment 7 in Reference 4).

2. McGuire TS 3.7.15 will be revised to provide revised spent fuel pool storage criteria and revised fuel enrichment and burnup requirements for McGuire Region 2A. With the applicable minimum concentration of soluble boron present in the spent fuel storage pool and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels in Region 2A, these changes will ensure that the pool storage rack $k_{eff}$ is $\leq 0.95$ under non-accident conditions (including the unlikely occurrence of a worst-case spent fuel storage pool dilution event with thorough mixing) and accident conditions. The applicable minimum concentration of soluble boron is ensured by existing McGuire TS 3.7.14.

   In the unlikely event of a worst case spent fuel storage pool dilution event without thorough mixing, the proposed changes will ensure that the pool storage rack $k_{eff}$ is < 1.0 under non-accident conditions with no credit for soluble boron and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels in Region 2A.

3. McGuire TS 3.7.15 will also be revised to require more restrictive boundary conditions between storage regions for McGuire Regions 1B and 2A. Boundary conditions for Region 1B are changing because of a change to the required shape of the storage configurations. Currently, Region 1B storage configurations must be rows extending from one side of the rack to the other side. The proposed more restrictive storage configurations will allow storage in rectangular arrays of any size. Boundary conditions for Region 2A are changing due to the change from 50% boraflex credit to 40% boraflex credit.

As stated above, the proposed changes are based upon the assumptions of the amount of Boraflex remaining in the pools as described in the McGuire Spent Fuel Pool Criticality Analysis. Chapter 16 of the McGuire UFSAR, "Selected Licensee Commitments", provides for periodic monitoring of future Boraflex degradation. If this monitoring determined that the Boraflex in a spent fuel storage pool degraded to levels that would not support the conclusions of the McGuire Spent Fuel Pool Criticality Analysis, then a future LAR would be submitted proposing additional changes to the McGuire TSs and spent fuel storage pool design bases as needed to maintain acceptable levels of subcriticality in the McGuire fuel pools.

## Technical Justification

Normal Conditions:

The redefined McGuire Region 2A spent fuel storage racks were analyzed taking credit for soluble boron as allowed in the NRC approved "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" described in WCAP-14416-NP-A (Reference 1).

Utilizing the spent fuel pool storage configurations, spent fuel pool storage criteria, and the fuel enrichment and burnup requirements described in the McGuire Spent Fuel Pool Criticality Analysis (Attachment 6), that analysis demonstrates that under non-accident conditions a spent fuel storage pool boron concentration of 850 ppm would be adequate to maintain the spent fuel storage rack $k_{eff} \leq 0.95$ with credit for the presence of IFBA rods where applicable, and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels. Existing McGuire TS 3.7.14 states that the spent fuel pool storage boron concentrations shall be maintained within the limits specified in the McGuire Core Operating Limits Report (COLR). The spent fuel pool boron concentration limit currently specified in the COLR is 2675 ppm which is well above the minimum required boron credit of 850 ppm for non-accident conditions.

It is possible that the boron concentration in the spent fuel storage pool could be lowered below the COLR limit by a pool dilution event. Consequently, an analysis of dilution event spent fuel storage pool boron concentrations is necessary to ensure that acceptable levels of subcriticality are maintained during and following the event (Attachment 7 in Reference 4). Note that based upon the double contingency principle, this dilution event is assumed to occur under non-accident conditions. As part of this spent fuel storage pool dilution event analysis, calculations were performed to define the dilution time and volumes for the spent fuel pool. The dilution sources available at McGuire were compiled and evaluated against the calculated dilution volume to identify the bounding dilution event. The McGuire dilution analysis concluded that the bounding event was dilution from the McGuire Recycle Holdup Tanks (RHTs) while they are in "piggy-back" alignment with the Reactor Makeup Water Storage Tank (RMWST) and the spent fuel storage pool cask loading pit is isolated and drained. Given the volume of water in these tanks and the capacity of the pumps in the flow path to a spent fuel storage pool, the dilution analysis determined that it would take over 2-½ days for all the water in these tanks to be added to a fuel pool. It is likely that such a worst case dilution event would be detected by a spent fuel storage pool level alarm or by plant operations personnel walking through the area before the entire volume of the RHTs and the RMWST was added to the fuel pool. Note that in the unlikely event this worst case dilution event was not detected and the entire volume of the three tanks was transferred to a fuel pool, the dilution analysis indicates that the boron concentration of a pool would be reduced to approximately 937 ppm assuming a conservative starting boron concentration of 2475 ppm and thorough mixing of the non-borated water added to a pool. This post-dilution boron concentration is well above the minimum required boron credit of 850 ppm for non-accident conditions. Note that the above post-dilution event boron concentrations are based upon the assumption that all of the non-borated water added to a spent fuel pool is thoroughly mixed with the water in the pool. Given the spent fuel storage pool cooling water flow and convection from the spent fuel decay heat, it is likely that this thorough mixing would occur. However, if mixing was not adequate, it is possible that a localized pocket of non-borated water could form somewhere in the spent fuel pool. This possibility is addressed by the calculation in Attachment 6 which shows that a spent fuel storage pool $k_{eff}$ will still be less than 1.0 on a 95/95 basis with the spent fuel pool filled with non-borated water. Thus, in the unlikely event that the worst case dilution event occurred and then a pocket of non-borated water formed in the spent fuel pool due to inadequate mixing, acceptable subcritical conditions would still be maintained in the McGuire spent fuel storage pools.

Accident Conditions:

Many of the postulated spent fuel pool accidents at McGuire will not result in an increase in $k_{eff}$ of the spent fuel racks. Such accidents are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules, and the drop of a fuel assembly between rack modules and the pool wall. At McGuire, the spent fuel assembly rack configuration is such that it precludes the insertion of a fuel assembly between rack modules. The placement of an assembly between the rack and the pool wall would result in a lower $k_{eff}$ relative to the criticality analysis due to the increased neutron leakage at the spent fuel pool wall because the criticality analysis assumes an infinite array of fuel assemblies. In the case where a dropped fuel assembly in its most reactive condition is dropped onto the spent fuel racks, it is assumed that the rack structure pertinent for criticality is not excessively deformed. For this event, previous accident analysis with unborated water showed that a dropped fuel assembly resting horizontally on top of the spent fuel rack has sufficient water separating it from the active fuel height of stored fuel assemblies to preclude neutronic interaction.

However, three accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. If a fuel assembly were to be dropped or placed into the cask loading area of a pool, any reactivity increase would be bounded by the fuel assembly misload accident described below. The other two postulated accidents which need to be addressed are a significant change in the spent fuel pool water temperature and the misloading of a fuel assembly. A fuel assembly misload accident relates to the use of restricted storage locations based on fuel assembly type, initial enrichment, burnup and IFBA rod loading requirements. The misloading of a fuel assembly constitutes not meeting the enrichment, burnup or IFBA rod requirements of that restricted location. The result of the misloading is to add positive reactivity, increasing $k_{eff}$ toward 0.95. Note that special administrative controls are placed on the patterning and region loading of assemblies into these restricted locations. A significant change in the spent fuel pool water temperature can be caused by either the loss of normal cooling to the spent fuel pool water which causes an increase in the temperature of the water passing through the stored fuel assemblies or a large makeup to the pool with cold water which could happen if the spent fuel pool were used as an emergency source of borated water. The loss of spent fuel pool cooling causes a decrease in water density which would result in a decrease in reactivity when Boraflex neutron absorber panels are present in the racks. However, since Boraflex is not considered to be present for some regions and the spent fuel pool water has a high concentration of boron, a density decrease results in a decrease in boron density which causes a positive reactivity addition. The decrease in pool temperature causes an increase in water density which would normally result in an increase in reactivity.

For each Region 2A storage configuration proposed in the revised TS 3.7.15, a McGuire spent fuel rack criticality analysis was performed as described in the McGuire Spent Fuel Pool Criticality Analysis (Attachment 6). This revised McGuire Criticality Analysis evaluated the amount of soluble boron necessary to ensure that the Region 2A spent fuel rack $k_{eff}$ will be maintained less than or equal to 0.95 following a significant change in spent fuel pool temperature or the misloading of a fuel assembly. For each of these accidents, that evaluation established that a minimum boron concentration of 1470 ppm is sufficient to maintain $k_{eff}$ less than or equal to 0.95. A separate McGuire TS states that the spent fuel pool storage boron concentrations shall be maintained within the limits specified in the McGuire Core Operating Limits Report (COLR). The spent fuel pool boron concentration limit currently specified in the COLR is 2675 ppm. Consequently, under the applicable accident conditions, maintaining spent fuel pool boron concentrations within the COLR limit will ensure that the spent fuel storage rack $k_{eff}$ is $\leq$ 0.95 when fuel is stored in accordance with the revised spent fuel pool storage configurations, revised spent fuel pool storage criteria and revised fuel enrichment and burnup requirements specified in the proposed change to TS 3.7.15. Note that, based on the double contingency principle, the margin for accident conditions included in the boron concentration limit does not have to account for both a loss of cooling accident, a misload accident, or a spent fuel pool dilution event occurring at the same time.

## Conclusion

Revision of the McGuire TS's and design bases as proposed in this LAR will provide a level of safety comparable to the conservative criticality analysis methodology required by References 1, 2, and 3 of this attachment. Consequently, the health and safety of the public will not be adversely affected by the proposed Technical Specification changes. The bases for these conclusions are as follows:

1. Utilizing the revised spent fuel pool storage criteria and revised fuel enrichment and burnup requirements specified in the proposed change to TS 3.7.15, the McGuire Spent Fuel Pool Criticality Analysis demonstrates that, under non-accident conditions (including thorough mixing of pool water following the unlikely occurrence of a worst case spent fuel storage pool dilution event), a minimum spent fuel storage pool boron credit of 850 ppm would be adequate to maintain the spent fuel storage rack $k_{eff}$ $\leq$ 0.95 with credit for the presence of IFBA rods where applicable and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels. This minimum boron concentration would be ensured by existing McGuire TS 3.7.14.

2. Utilizing the revised spent fuel pool storage criteria and revised fuel enrichment and burnup requirements specified in the proposed change to TS 3.7.15, the McGuire Spent Fuel Pool Criticality Analysis demonstrates that, under non-accident conditions and non-thorough mixing of pool water following the unlikely occurrence of a worst case spent fuel storage pool dilution event, spent fuel storage rack $k_{eff}$ would remain < 1.0 with credit for the presence of IFBA rods where applicable and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels.

3. Utilizing the revised spent fuel pool storage criteria, revised fuel enrichment and burnup requirements specified in the proposed change to TS 3.7.15, the McGuire Spent Fuel Pool Criticality Analysis demonstrates that under accident conditions a minimum spent fuel storage pool boron credit of 1470 ppm would be adequate to maintain the spent fuel storage rack $k_{eff} \leq 0.95$ with credit for the presence of IFBA rods where applicable, and reduced credit for the degraded spent fuel rack Boraflex neutron absorber panels. This minimum boron concentration would be ensured by existing McGuire TS 3.7.14.

Note that the existing TS 3.7.15 specifies the requirements for spent fuel pool storage configurations, fuel pool storage criteria, fuel enrichment, and fuel burnup. Consequently, plant operating procedures already include controls to ensure these existing requirements are satisfied. These procedural controls will be revised and maintained as needed under the revised TS 3.7.15. Note that existing McGuire spent fuel pool storage systems, supporting systems, and instrumentation are not modified as a result of this proposed LAR.

References

1. WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology", Revision 1, November 1996.

2. USNRC Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, NUREG-0800, June 1987.

3. USNRC Spent Fuel Storage Facility Design Bases (for Comment) Proposed Revision 2, 1981, Regulatory Guide 1.13.

4. Proposed Technical Specification (TS) Amendments {TS 3.7.15 & TS 4.3}, Duke Energy Corporation, McGuire Nuclear Station Units 1 and 2 (Docket Nos. 50-369/50-370), August 1, 2000.

# ATTACHMENT 4

# NO SIGNIFICANT HAZARDS CONSIDERATION EVALUATION

No Significant Hazards Consideration Evaluation

In accordance with the criteria set forth in 10 CFR 50.91 and 50.92, McGuire Nuclear Station has evaluated the proposed Technical Specification change and determined it does not represent a significant hazards consideration. The following is provided in support of this conclusion.

The radiological consequences of a fuel handling accident in the spent fuel pool do not change by taking credit for soluble boron in the pool because the current spent fuel pool boron concentration limit is not being changed. The radiological consequences also do not change as a result of reducing the minimum Region 2A rack poison requirement from 50% Boraflex remaining to 40% Boraflex remaining, because the revised Region 2A storage burnup limits still meet the required level of subcriticality for all normal and accident conditions.

1. Will the change involve a significant increase in the probability or consequence of an accident previously evaluated?

   No, based upon the following:

   Dropped Fuel Assembly

   There is no significant increase in the probability of a fuel assembly drop accident in the spent fuel pools when considering the degradation of the Boraflex panels in the spent fuel pool racks coupled with the presence of soluble boron in the spent fuel pool water for criticality control. The handling of the fuel assemblies in the spent fuel pool has always been performed in borated water, and the quantity of Boraflex remaining in the racks has no effect on the probability of such a drop accident.

   The criticality analysis showed that the consequences of a fuel assembly drop accident in the spent fuel pools are not affected when considering the degradation of the Boraflex in the spent fuel pool racks and the presence of soluble boron.

   Fuel Misloading

   There is no significant increase in the probability of the accidental misloading of spent fuel assemblies into the spent fuel pool racks when considering the degradation of the Boraflex in the spent fuel pool racks and the presence of soluble boron in the pool water for criticality control. Fuel assembly placement and storage will continue to be controlled pursuant to approved fuel handling procedures to ensure compliance with the Technical Specification requirements. These procedures will be revised as needed to comply with the revised Region 2A requirements which would be imposed by the proposed Technical Specification changes. These revised storage limits were developed with input from station personnel. Their awareness, in conjunction with any procedure changes as described above, will provide additional assurance that an accidental misloading of a spent fuel assembly should not occur.

There is no increase in the consequences of the accidental misloading of spent fuel assemblies into the spent fuel pool racks because criticality analyses demonstrate that the pool will remain subcritical following an accidental misloading if the pool contains an adequate soluble boron concentration. Current Technical Specification 3.7.14 will ensure that an adequate spent fuel pool boron concentration is maintained in the McGuire spent fuel storage pools. The McGuire Station UFSAR Chapter 16, "Selected Licensee Commitments", provides for adequate monitoring of the remaining Boraflex in the spent fuel pool racks. If that monitoring identifies further reductions in the Boraflex panels which would not support the conclusions of the McGuire Criticality Analysis, then the McGuire TSs and design bases would be revised as needed to ensure that acceptable subcriticality are maintained in the McGuire spent fuel storage pools.

<u>Significant Change in Spent Fuel Pool Temperature</u>

There is no significant increase in the probability of either the loss of normal cooling to the spent fuel pool water or a decrease in pool water temperature from a large emergency makeup when considering the degradation of the Boraflex in the spent fuel pool racks and the presence of soluble boron in the pool water for subcriticality control since a high concentration of soluble boron has always been maintained in the spent fuel pool water. Current Technical Specification 3.7.14 will ensure that an adequate spent fuel pool boron concentration is maintained in the McGuire spent fuel storage pools

A loss of normal cooling to the spent fuel pool water causes an increase in the temperature of the water passing through the stored fuel assemblies. This causes a decrease in water density that would result in a decrease in reactivity when Boraflex neutron absorber panels are present in the racks. However, since a reduction in the amount of Boraflex present in the Region 2A racks is considered, and the spent fuel pool water has a high concentration of boron, a density decrease causes a positive reactivity addition. However, the additional negative reactivity provided by the current boron concentration limit, above that provided by the concentration required to maintain $k_{eff}$ less than or equal to 0.95 (1470 ppm), will compensate for the increased reactivity which could result from a loss of spent fuel pool cooling event. Because adequate soluble boron will be maintained in the spent fuel pool water, the consequences of a loss of normal cooling to the spent fuel pool will not be increased. Current Technical Specification 3.7.14 will ensure that an adequate spent fuel pool boron concentration is maintained in the McGuire spent fuel storage pools.

A decrease in pool water temperature from a large emergency makeup causes an increase in water density that would result in an increase in reactivity when Boraflex neutron absorber panels are present in the racks. However, the additional negative reactivity provided by the current boron concentration limit, above that provided by the concentration required to maintain $k_{eff}$ less than or equal to 0.95 (1470 ppm), will compensate for the increased reactivity which could result from a decrease in spent fuel pool water temperature. Because adequate soluble boron will be maintained in the spent fuel pool water, the consequences of a decrease in pool water temperature will not be increased. Current Technical Specification 3.7.14 will ensure that an adequate spent fuel pool boron concentration is maintained in the McGuire spent fuel storage pools.

2. Will the change create the possibility of a new or different kind of accident from any previously evaluated?

No. Criticality accidents in the spent fuel pool are not new or different types of accidents. They have been analyzed in Section 9.1.2.3 of the Updated Final Safety Analysis Report and in Criticality Analysis reports associated with specific licensing amendments for fuel enrichments up to 4.75 weight percent U-235. Specific accidents considered and evaluated include fuel assembly drop, accidental misloading of spent fuel assemblies into the spent fuel pool racks, and significant changes in spent fuel pool water temperature. The accident analysis in the Updated Final Safety Analysis Report remains bounding.

The possibility for creating a new or different kind of accident is not credible. The amendment proposes to take credit for the soluble boron in the spent fuel pool water for reactivity control in the spent fuel pool while maintaining the necessary margin of safety. Because soluble boron has always been present in the spent fuel pool, a dilution of the spent fuel pool soluble boron has always been a possibility; however, a criticality accident resulting from a dilution accident was not considered credible. A spent fuel pool dilution evaluation (Attachment

7 in Reference 7) has demonstrated that a dilution of the boron concentration in the spent fuel pool water which could increase the rack $k_{eff}$ to greater than 0.95 (constituting a reduction of the required margin to criticality) is not a credible event. The requirement to maintain a revised minimum boron concentration in the spent fuel pool water for reactivity control (at least 850 ppm) will have no effect on normal pool operations and maintenance. There are no changes in equipment design or in plant configuration. This revised requirement will not result in the installation of any new equipment or modification of any existing equipment. Therefore, the proposed amendment will not result in the possibility of a new or different kind of accident.

3. Will the change involve a significant reduction in a margin of safety?

No. The proposed Technical Specification changes and the resulting McGuire Region 2A spent fuel storage operating limits will provide adequate safety margin to ensure that the stored fuel assembly array will always remain subcritical. Those revised limits are based on a plant specific criticality analysis (Attachment 6) based on the "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" described in Reference 1. The Westinghouse methodology for taking credit for soluble boron in the spent fuel pool has been reviewed and approved by the NRC (Reference 6). This methodology takes partial credit for soluble boron in the spent fuel pool and requires conformance with the following NRC acceptance criteria for preventing criticality outside the reactor:

1) $k_{eff}$ shall be less than 1.0 if fully flooded with unborated water which includes an allowance for uncertainties at a 95% probability, 95% confidence (95/95) level; and

2) $k_{eff}$ shall be less than or equal to 0.95 if fully flooded with borated water, which includes an allowance for uncertainties at a 95/95 level.

The criticality analysis utilized credit for soluble boron to ensure $k_{eff}$ will be less than or equal to 0.95 under normal circumstances, and storage configurations have been defined using a 95/95 $k_{eff}$ calculation to ensure that the spent fuel rack $k_{eff}$ will be less than 1.0 with no soluble boron. Soluble boron credit is used to provide safety margin by maintaining $k_{eff}$ less than or equal to 0.95 including uncertainties, tolerances and accident conditions in the presence of spent fuel pool soluble boron. The loss of substantial amounts of soluble boron from the spent fuel pool which could lead to exceeding a $k_{eff}$ of 0.95 has been evaluated (Attachment 7 in Reference 7) and shown to be not credible. Accordingly, the required margin to criticality is not reduced.

Previous evaluations (Attachment 7 in Reference 7) have shown that the dilution of the spent fuel pool boron concentration from the conservative assumed initial boron concentration (2475 ppm) to the minimum boron concentration required to maintain $k_{eff} \leq 0.95$ (850 ppm) is not credible. The dilution analyses, along with the 95/95 criticality calculation which shows that the spent fuel rack $k_{eff}$ will remain less than 1.0 when flooded with unborated water, provide a level of safety comparable to the conservative criticality analysis methodology required by References 2, 3 and 4.

Therefore, the proposed changes in this license amendment will not result in a significant reduction in the facility's margin of safety.

References


1. WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology", Revision 1, November 1996.

2. USNRC Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, NUREG-0800, June 1987.

3. USNRC Spent Fuel Storage Facility Design Bases (for Comment) Proposed Revision 2, 1981, Regulatory Guide 1.13.

4. ANS, Design Requirements for Light Water Reactor Spent Fuel Storage Facilities at Nuclear Power Stations, ANSI/ANS-57.2-1983.

5. Attached McGuire Criticality Analysis and other attached documentation (including references therein) forming the basis for this license amendment request.

6. Letter from TE Collins (NRC) to T Greene (WOG), Acceptance for Referencing of Licensing Topical Report WCAP-14416-P, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology." (TAC No. M93254), Dated October 15, 1996.

7. Proposed Technical Specification (TS) Amendments {TS 3.7.15 & TS 4.3}, Duke Energy Corporation, McGuire Nuclear Station Units 1 and 2 (Docket Nos. 50-369/50-370), August 1, 2000.

# ATTACHMENT 5

# ENVIRONMENTAL IMPACT ASSESSMENT

Environmental Impact Assessment:

The proposed Technical Specification amendment has been reviewed against the criteria of 10 CFR 51.22 for environmental considerations. The proposed amendment will allow credit to be taken for soluble boron in the spent fuel storage pool water to maintain an acceptable margin of subcriticality for redefined Region 2A fuel storage limits. Appropriate controls are in place to monitor the soluble boron concentration in the spent fuel pool water and to monitor for future degradation of the Boraflex panels in the spent fuel storage cells. Consequently, the proposed amendment does not involve a significant hazards consideration, nor increase the types and amounts of effluents that may be released offsite, nor increase individual or cumulative occupational radiation exposures. Therefore, the proposed amendment meets the criteria given in 10 CFR 51.22(c)(9) for a categorical exclusion from the requirement for an Environmental Impact Assessment.

# ATTACHMENT 6

# MCGUIRE SPENT FUEL POOL CRITICALITY ANALYSIS

# MCGUIRE SPENT FUEL POOL CRITICALITY ANALYSIS

## Table of Contents

## 1.0 INTRODUCTION

This attachment describes the criticality analysis of the McGuire Nuclear Station spent fuel storage racks. This analysis takes credit for soluble boron in the spent fuel pool water as allowed in Reference 8.1 of this attachment.

It should be noted that the Westinghouse methodology in Reference 8.1 was used as the basis for the methodology used in this analysis. However, since this analysis was performed by Duke Energy, some minor differences in the application of the methodology exist. For example, this analysis used a different set of computer codes to perform the calculations (as described in Section 2.0) instead of those described in Reference 8.1. So, while the process and criteria defined in the "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" were followed, the methodology used for this submittal, which is based on the Westinghouse methodology, is described in this attachment.

The storage rack design for the McGuire spent fuel pools is a two region design. Each region utilizes the poison material Boraflex. Due to the degradation of the Boraflex poison material and the need to establish acceptable spent fuel storage limits, each region has been divided into two sub-regions; with and without credit for Boraflex. For the regions taking credit for Boraflex, a minimum amount of Boraflex was assumed that is less than the original design minimum $B_{10}$ areal density. The sub-regions are defined as follows:

- Region 1A takes credit for 25% of the original Boraflex material
- Region 1B takes no credit for Boraflex
- Region 2A takes credit for 40% of the original Boraflex material
- Region 2B takes no credit for Boraflex

Within each sub-region, the criticality analysis takes credit for burnup and storage configuration restrictions to achieve acceptable spent fuel storage limits. Two storage configurations are defined for each of the four regions: Unrestricted and Restricted storage. A third loading pattern, Checkerboard storage, was defined for Regions 1B, 2A and 2B. Unrestricted storage allows storage in all cells without restriction on the storage configuration. Restricted storage allows storage of higher reactivity fuel when restricted to a certain storage configuration with lower reactivity fuel. Checkerboard storage allows storage of the highest reactivity fuel in each region when checkerboarded with empty storage cells.

In addition, credit is also taken for Integrated Fuel Burnable Absorbers (IFBAs). IFBA credit is only taken for Region 1A since this is the region where the new fuel will be stored prior to refueling the reactor.

The main design criteria for the McGuire spent fuel storage rack criticality analysis is that $k_{eff} < 1.0$ with no boron (including tolerances and uncertainties) and $k_{eff} \leq 0.95$ with credit for soluble boron. The soluble boron credit required for the storage configurations in all regions is 850 ppm for normal conditions and 1470 ppm for accident conditions.

## 1.1 Spent Fuel Storage Rack Design

McGuire has two independent identical spent fuel pools for Units 1 and 2. The spent fuel storage rack in each pool consists of a two-region design.

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. The stainless steel cells are spaced at 10.4 inches and were constructed with a minimum 0.02 gm/cm$^2$ loading of $B_{10}$ neutron absorbing material attached to the exterior cell wall wrapper plate. Region 1 has a capacity which is just sufficient to accommodate both a complete off load of the reactor core and storage of a reload fuel batch. With the larger fuel batch sizes to accommodate McGuire's 18-month cycle lengths, there are very few unused cells in Region 1 during an outage.

The basic spent fuel storage pool rack arrangement for Units 1 and 2 is shown in Figure 1. The Region 1 area of the pool is highlighted and a schematic of the Region 1 cell configuration is also 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. This configuration has a much tighter center-to-center pitch of 9.125 inches. These cells also utilize a neutron absorbing material with a slightly lower minimum $B_{10}$ areal density (0.006 gm/cm$^2$) than that used in Region 1. This region has a nominal capacity of 1177 locations.

The basic spent fuel storage pool rack arrangement for Units 1 and 2 is shown again in Figure 2 with the Region 2 area of the pool highlighted and a schematic of the Region 2 cell configuration provided.

## 1.2 New Fuel Storage Vault Design

The new fuel storage vaults which are used for temporary dry storage of unirradiated reload fuel are built on 21 inch centers and are currently licensed for maximum nominal fuel enrichments of 4.75 %U-235. To accommodate a new Westinghouse Performance Plus fuel design, previously approved analytical methods were used to demonstrate that this new fuel containing up to 4.75% 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 3.3. No technical specification changes are applicable to the new fuel storage vaults.

## 2.0 COMPUTER CODES AND METHODOLOGY

The methodology employed in this analysis is based on the "Westinghouse Spent Fuel Rack Criticality Analysis Methodology" (Reference 8.1). While, the process and criteria defined in the Westinghouse methodology were followed, the methodology used for this submittal, which is based on the Westinghouse methodology, is described in this attachment.

The methodology employed in this analysis uses both the CASMO-3/TABLES-3/SIMULATE-3 and SCALE system of codes for criticality analysis. CASMO-3/TABLES-3/SIMULATE-3 is used primarily and SCALE with KENO-Va is used for limited applications.

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 methodology 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 incore depletion calculations and resulting fuel isotopics with out-of-core storage array criticality analyses. The CASMO-3/TABLES-3/SIMULATE-3 methodology has been previously approved for use in criticality analysis of the McGuire spent fuel storage racks (Reference 8.2).

The CASMO-3/TABLES-3/SIMULATE-3 methodology is 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 (Reference 8.3). The B&W critical experiments used are specifically designed for benchmarking reactivity calculation techniques. 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.

The results of the CASMO-3/TABLES-3/SIMULATE-3 benchmark calculations are shown in Table 1. There are no significant trends in the results with respect to moderator soluble boron concentration, array spacing, or boron level in the isolation sheets.

The SCALE system of computer codes was used to model the Checkerboard storage configurations, new fuel storage vault and various biases and uncertainties related to the Boraflex material (self shielding, shrinkage and gaps). This methodology utilizes three dimensional Monte Carlo theory. 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-4.2 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 27 Group NDF4 cross section library was used exclusively for this analysis.

The KENO-Va methodology is also benchmarked to measured results of fuel storage critical experiments. The criticality experiments used to benchmark the KENO-Va methodology were from the PNL reports PNL-3314 (Reference 8.4), PNL-2438 (Reference 8.5) and PNL-6205 (Reference 8.6). 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.

The results of the KENO-Va benchmark calculations are shown in Table 2. There are no significant trends in the results with respect to fuel pin spacing, array spacing, poison loading and material or fuel enrichment.

For additional verification that the models used in the McGuire criticality analysis are accurate, calculated $k_{eff}$s from CASMO-3, SIMULATE-3 and KENO-Va are compared in Table 3. The results listed in Table 3 show very good agreement between the transport theory, diffusion theory and Monte Carlo codes, with CASMO-3 and SIMULATE-3 being slightly conservative compared to KENO-Va.

## 3.0 CRITICALITY ANALYSIS

This section describes the criticality analysis performed to determine the spent fuel storage limits for the McGuire spent fuel storage racks.

The following assumptions are used in the spent fuel pool criticality analysis.

1. All fuel designs stored, or planned for storage, at McGuire were analyzed. This included Westinghouse Standard (STD), Optimized (OFA) and Robust Fuel (RFA, also referred to as Performance Plus or PF+) and Framatome Mark BW (MkBW) fuel designs. Also included were the Oconee fuel assemblies currently stored at McGuire. All fuel designs are analyzed for all cases and only the most reactive fuel design is used to set the storage requirements.

2. All conditions are modeled at both 68 and 150 $^{o}$F. Only the most reactive temperature is used to set the storage requirements.

3. Most calculations are 2-D; i.e. no axial effects are modeled. A reactivity bias is included in the 2-D calculations to account for differences between 2-D and 3-D modeling.

4. No xenon conditions are assumed in the storage racks.

5. No credit is taken for the spacer grid material.

6. McGuire Region 1A contains 25% of its original thickness and areal density.

7. McGuire Region 1B contains no Boraflex.

8. McGuire Region 2A Boraflex contains 40% of its original thickness and areal density.

9. McGuire Region 2B contains no Boraflex.

10. The Boraflex panels are reduced in the width direction to account for 0.25 inches assumed shrinkage.

11. The Boraflex panels are reduced in the axial direction to account for measured shrinkage.

12. No reactivity penalty is included for gaps in the Boraflex panels (see Section 3.1).

13. The nominal coating on IFBA rods is assumed to be 1.0X which

is the minimum standard loading offered by the vendor. The IFBA coating is reduced to 75% of this value to account for the IFBA coating not being applied for the full length of the fuel rod.

## 3.1 No Boron 95/95 $k_{eff}$

This section describes the methodology used to determine the limits for the $k_{eff}$ calculation with no boron including all biases and uncertainties (95/95 $k_{eff}$).

The 95/95 $k_{eff}$ must be less than 1.0 with no boron. The calculation of the 95/95 $k_{eff}$ must consider various biases and uncertainties related to the materials and construction of the racks. Specifically, the biases and uncertainties accounted for in the McGuire spent fuel pool criticality analysis are the bias and uncertainty associated with the benchmarking of the methodology, biases and uncertainties associated with the affect of Boraflex shrinkage, a bias to account for the underprediction of reactivity due to self shielding, a bias to account for 3-dimensional effects not captured by the 2-dimensional model and the uncertainty due to mechanical tolerances from the manufacturing process. The mechanical tolerance uncertainty is comprised of the following components: cell ID, CTC spacing, cell thickness, Boraflex width, plenum thickness, enrichment, fuel pellet dish volume, fuel pellet theoretical density, fuel pellet OD, clad OD and assembly position within the storage cell. For the no boron 95/95 $k_{eff}$, these biases and uncertainties are generated at no boron conditions. Additional uncertainties related to burned fuel are discussed with the burnup credit methodology. Table 4 lists the biases and uncertainties for each region.

The uncertainties associated with the effect of Boraflex shrinkage include the following. A reactivity bias is included to account for an assumed 0.25 inches of shrinkage in the width of the Boraflex panels. A reactivity uncertainty is included to account for the 95/95 worst case shrinkage in the axial direction (end pullback of the top and bottom). No reactivity penalty is included to account for gaps in the middle of the Boraflex panels, nor are any gaps included in the models. However, an analysis was performed to determine the maximum gap size before an increase in reactivity occurs. This analysis looked at a gap in one out of four panels, two out of four and four out of four panels. The results of this analysis indicate that the size gap required before an increase in reactivity is observed is less than the size of gaps observed in recent measured data. Hence, no reactivity penalty is necessary to account for gaps in the

Boraflex panels.

A no boron 95/95 maximum design $k_{eff}$ is defined to be 1.0 less the combination of all the biases and uncertainties. For the final $k_{eff}$ to remain less than 1.0, the calculated $k_{eff}$ must remain less than the no boron maximum design $k_{eff}$. Since the combined biases and uncertainties are dependent on the fuel storage rack, four no boron 95/95 maximum design $k_{eff}$s are defined, one for each region of the pool. These maximum design $k_{eff}$s are listed in Table 4.

To determine the maximum enrichment for Unrestricted storage, CASMO-3 is used to iterate on enrichment until the calculated $k_{eff}$ from CASMO-3 meets the no boron 95/95 maximum design $k_{eff}$. Since CASMO-3 is a lattice code, its calculations are for single assemblies in an infinite array, which is representative of the Unrestricted 100% storage option. The results of the fresh fuel limits for Unrestricted storage are summarized in Table 6.

Assemblies which do not qualify for unrestricted storage must be stored in a restricted storage configuration. Two restricted storage configurations are employed; Restricted storage with low reactivity 'filler' assemblies in a specified storage pattern and Checkerboard storage with empty cells in a specified storage pattern.

For Restricted storage to be effective, the storage requirements must be carefully selected to optimize the use of the spent fuel storage cells for the current and expected inventory of fuel for each region. For this reason, a different Restricted storage pattern is defined for each region of the McGuire spent fuel pools. For Region 1A, a 3 out of 4 storage pattern is defined which allows assemblies not qualified for Unrestricted storage to be stored in 3 out of every 4 locations with the $4^{th}$ being a qualified low reactivity 'filler' assembly. This storage pattern is shown in Figure 3. For Regions 1B and 2A, two different checkerboard storage patterns are defined which allow assemblies not qualified for Unrestricted storage to be stored in 2 out of every 4 locations with the other 2 being qualified low reactivity 'filler' assemblies. This storage pattern is shown in Figure 4. For Region 2B, a 1 out of 4 storage pattern is defined which allows assemblies not qualified for Unrestricted storage to be stored in 1 out of every 4 locations with the other 3 being qualified low reactivity 'filler' assemblies. This storage pattern is shown in Figure 5. By storing the more reactive assemblies not qualified for Unrestricted storage with less reactive fuel, the overall reactivity of the array is able to stay beneath the no boron 95/95 maximum design $k_{eff}$. The Unrestricted and Restricted storage patterns for each region will allow optimum usage of all the storage cells in the McGuire racks for a wide range of fuel assemblies.

Prior to performing any reactivity calculations, the requirements of either the filler or restricted assemblies must be selected. In this analysis, the requirements for the restricted assemblies were selected first and the filler requirements were then calculated for the restricted assembly requirements chosen. The fresh fuel limits defined for Restricted storage are summarized in Table 6.

The maximum enrichment for the Filler fuel in the Restricted storage configurations is calculated using SIMULATE-3. To model the Restricted storage patterns, the model must have the ability to analyze different assemblies in the same problem. This required the nodal code. SIMULATE-3 was executed to calculate $k_{eff}$ of the Restricted storage array containing dissimilar fuel. The maximum enrichment for the filler fuel is determined by iterating on enrichment until the calculated $k_{eff}$ from SIMULATE-3 meets the no boron 95/95 maximum design $k_{eff}$. The results of the fresh fuel limits for Filler fuel in the Restricted storage configuration are summarized in Table 6.

Assemblies which do not qualify for Unrestricted or Restricted storage must be stored in a checkerboard storage pattern with empty storage locations. Checkerboard storage will allow storage of all fuel in each region.

The goal of Checkerboard storage is to be able to store the most reactive fuel assembly in each region. This is accomplished by storing the most reactive assembly with empty storage locations to keep the overall reactivity of the array beneath the required reactivity limit. To determine the storage pattern for Checkerboard storage, the calculated $k_{eff}$ is varied by varying the number of empty cells until the calculated $k_{eff}$ is less than or equal to the maximum design $k_{eff}$. The calculated $k_{eff}$s are taken from KENO-Va. A different Checkerboard storage pattern is defined for each region of the McGuire spent fuel pools. Since restricted storage for Region 1A includes fuel up to the maximum allowed enrichment, Checkerboard storage is not necessary for this region. The Checkerboard storage patterns are shown in Figures 6 and 7.

While it is intended to use the Unrestricted and Restricted storage patterns for optimum usage of all the storage cells, Checkerboard storage allows storage of the most reactive fuel in all regions if it becomes necessary.

### 3.1.1 No Boron 95/95 $k_{eff}$ -Burnup Credit

In order to store fuel with enrichments higher than the maximum enrichment limits for fresh fuel, the concept of reactivity equivalencing is employed. Reactivity equivalencing determines an equivalent reactivity by introducing a reactivity effect that was not previously considered. In this case, the negative reactivity from fuel burnup is used to offset the positive reactivity from higher enrichments until the reactivity is equivalent to that of the fresh fuel maximum enrichment case (i.e. the no boron 95/95 maximum design $k_{eff}$).

To use burnup credit, additional uncertainties related to depleted fuel must also be accounted for. The only burnup related uncertainty included in the no boron 95/95 maximum design $k_{eff}$ calculation is the reactivity increase associated with the removal of Burnable Poison assemblies (BP-pull). All other burnup related uncertainties, namely the uncertainty on the calculated reactivity versus burnup, the uncertainty on the measured burnup and the bias related to the axial distribution of burnup will be accounted for with boron credit as discussed in Section 3.2.

A bias is applied in the burnup credit calculations to account for a reactivity increase due to the shadowing effect of a BP. For burnup credit calculations, the standard criticality assumption was made that no removable poisons are in the assembly. However, an assembly which has a BP removed after its first cycle of operation is more reactive than an assembly that never contained a BP. A BP-pull bias is applied to account for this affect. A study of a database of BP-pull data for McGuire determined a maximum BP-pull reactivity increase of 0.01 $\Delta k$ at 14 GWD/MTU. The bias is assumed to be linear from 0 GWD/MTU to the maximum bias at 14 GWD/MTU and is constant beyond 14 GWD/MTU. This is conservative because the reactivity of the BP-pulled assembly tends to approach the reactivity of the never BP'd assembly by EOL. For burnup credit calculations, the bias only needs to be applied for assemblies with burnup. Hence, for Unrestricted storage burnup credit calculations, CASMO-3 is used and hence, the entire bias is applied, since every assembly has burnup. For the SIMULATE-3 model used for the Restricted storage calculations, only the Filler fuel has burnup. The Restricted fuel is modeled as fresh fuel with the maximum enrichments from Table 6. Therefore, an appropriate ratio of the BP-pull bias is applied for the Restricted storage array since only part of the array has burnup.

Summarizing, the BP-pull bias for each region is as follows.

Unrestricted Storage All Regions BP-pull bias $= \frac{0.01 \times BU}{14}$

Restricted Storage Region 1A BP-pull bias $= \frac{0.0025 \times BU}{14}$

Restricted Storage Region 1B BP-pull bias $= \frac{0.005 \times BU}{14}$

Restricted Storage Region 2A BP-pull bias $= \frac{0.005 \times BU}{14}$

Restricted Storage Region 2B BP-pull bias $= \frac{0.0075 \times BU}{14}$

Where: BU = Assembly burnup in GWD/MTU up to a maximum of 14

To model fuel burnup, CASMO-3 was used to deplete the fuel under hot full power reactor conditions. CASMO-3 restarts were then performed to model the depleted assemblies in the storage racks. This ensures the reactivity of the depleted assembly is explicitly determined in the storage rack conditions. CASMO-3 restarts are performed at 5 GWD/MTU intervals from 0 to 60 GWD/MTU and at 0.5 w/o enrichment intervals from 2.0 to 4.5 w/o and the maximum enrichment of 4.75 w/o. A TABLES-3 library was also created from the CASMO-3 storage rack restart data to allow modeling the burned fuel in SIMULATE-3.

The burnup credit calculations are performed similar to the calculations that determined the maximum fresh fuel enrichments except that instead of varying the enrichment, the burnup is varied. As with the maximum fresh fuel enrichment calculations, for Unrestricted storage, the calculated $k_{eff}$s come from CASMO-3, specifically, the storage rack restart cases with burned fuel. For Restricted storage, the calculated $k_{eff}$s come from SIMULATE-3. The calculated $k_{eff}$s are used to determine minimum burnup limits for each enrichment to ensure that the 95/95 storage rack $k_{eff}$ is $< 1.0$. The burnup limit is the burnup where the calculated $k_{eff}$ equals the no boron maximum design $k_{eff}$ from Table 4 minus the appropriate BP-pull bias discussed above. The minimum burnup requirements for each enrichment are determined by linearly interpolating between the calculated burnups. This linear interpolation assumes that the calculated $k_{eff}$ vs. burnup curve is linear. This is a very good assumption over small ranges of burnup.

The minimum burnup requirements for each enrichment are then plotted versus burnup and enrichment to yield a storage curve. A separate storage curve is generated for each type of storage and each region. A fuel assembly qualifies for storage if its burnup and enrichment fall above the storage curve.

The results of the burnup credit calculations are summarized in Tables 7 through 9. The storage curves are shown in Figures 8 and 9.

### 3.1.2 No Boron 95/95 $k_{eff}$ -IFBA Credit

This section describes the methodology for reactivity equivalencing taking credit for integrated fuel burnable absorber (IFBA) rods. IFBA rods are fuel rods with a thin layer of $ZrB_2$ sprayed on the fuel pellet. This coating provides a reactivity holddown at beginning of cycle. For the criticality analysis, this coating provides an integral poison in the fuel that may be taken credit for in the analysis. Credit for normal burnable poison rods is not allowed since these poison components can be removed from the fuel assembly.

In order to store fresh fuel more efficiently, the concept of reactivity equivalencing is employed. Reactivity equivalencing determines an equivalent reactivity by introducing a reactivity effect that was not previously considered. In this case, IFBA rods are introduced into the calculation and the enrichment is varied until the calculated $k_{eff}$ is equivalent to that of the fresh fuel maximum enrichment case (i.e. the no boron 95/95 maximum design $k_{eff}$).

Credit for IFBA is only utilized in Region 1A, where the fresh fuel is to be stored. The reactivity of Regions 1B, 2A and 2B are such that there is no real benefit for IFBA credit since these regions will not typically store fresh fuel. The use of IFBA credit for fresh fuel in Region 1A will permit most of the fresh fuel to be stored within the limited number of locations available in this region.

The calculated $k_{eff}$s come from the infinite lattice code CASMO-3. The calculated $k_{eff}$s are used to determine maximum enrichment for each discrete number of IFBA rods to ensure that the 95/95 storage rack $k_{eff}$ is < 1.0. The maximum enrichment requirements for each number of IFBA rods are determined by iterating on enrichment until the calculated $k_{eff}$ is less than the no boron 95/95 maximum design $k_{eff}$.

The maximum enrichment requirements for each number of IFBA rods are then plotted versus enrichment and number of IFBA rods to yield an Unrestricted storage curve. A fuel assembly qualifies for Unrestricted storage if its enrichment and number of IFBA rods fall above the Unrestricted storage curve. Assemblies which fall below the Unrestricted storage curve must be stored in a Restricted loading pattern.

The results of the IFBA credit calculations are summarized in Table 10.

3.2 Boron Credit 95/95 $k_{eff}$

This section describes the methodology used to determine the amount of soluble boron required to maintain the 95/95 $k_{eff} \leq 0.95$. The soluble boron required consists of two components; the boron required to reduce the no boron 95/95 $k_{eff}$ from 1.0 to 0.95 and the boron required to account for uncertainties in the reactivity equivalencing methods. The sum of these two components of required boron represent the amount of soluble boron credit needed. This required boron concentration must be less than the amount of boron available for normal conditions. The amount of boron available for normal conditions is determined from an appropriate boron dilution analysis. Additional boron requirements are needed to compensate for reactivity increases as a result of postulated accidents. These are discussed in the Section 4.

Just as with the no boron 95/95 $k_{eff}$ calculation, the calculation of the soluble boron credit 95/95 $k_{eff}$ must consider various biases and uncertainties related to the materials and construction of the racks. The same biases and uncertainties for the no boron 95 percent probability at a 95 percent confidence level $k_{eff}$ are determined for the soluble boron credit 95/95 $k_{eff}$ calculation. The only difference in the calculation of the uncertainties is that the calculations are now performed with the boron concentration required to maintain $k_{eff}$ less than 0.95. Only the mechanical tolerance uncertainty was explicitly calculated with boron. Given the extremely small change in the uncertainty between no boron and boron conditions, and the significant amount of margin available in the amount of boron available, the Boraflex related uncertainties were not recalculated at boron conditions. Table 5 lists the boron credit biases and uncertainties for each region.

The soluble boron credit 95/95 maximum design $k_{eff}$ is then 0.95 less these biases and uncertainties. For the final $k_{eff}$ to remain less than 0.95, the calculated $k_{eff}$ must remain less than the boron credit maximum design $k_{eff}$. Since the combined biases and uncertainties are dependent on the fuel storage rack, four boron credit 95/95 maximum design $k_{eff}$s are defined, one for each region of the pool. These maximum design $k_{eff}$s are listed in Table 5.

To determine the boron concentration required for $k_{eff} \leq 0.95$, SIMULATE-3 is used to iterate on the boron concentration using the appropriate fresh fuel enrichment for each region until the calculated $k_{eff}$ from SIMULATE-3 is less than the soluble boron credit 95/95 maximum design $k_{eff}$. Two sets of cases are run for each region for Unrestricted and Restricted storage. The appropriate fresh fuel enrichments for each case are the maximum fresh fuel enrichments for Unrestricted and Restricted storage in each region shown in Table 6. This establishes the first part of the total soluble boron credit required without accidents.

In addition to the boron credit required to maintain $k_{eff} \leq 0.95$, boron credit is also used to compensate for uncertainties associated with the reactivity equivalencing methods. Two reactivity equivalencing methods are used in this analysis; burnup credit and IFBA credit.

For burnup credit, the uncertainties associated with this reactivity equivalencing method are as follows:

Burnup Credit Uncertainties
Calculated reactivity and depletion versus burnup
Measured burnup
Axial burnup distribution

The BP-pull reactivity increase is not included in the boron credit determination since it is already accounted for in the burnup limits.

Previous analysis for McGuire fuel determined an exposure reactivity bias of 0.0048 $\Delta k$ at 50 GWD/MTU to be applied linearly versus burnup. However, a more conservative value will be used which is consistent with other boron credit analyses. A value of 0.01 $\Delta k$ at 30 GWD/MTU applied linearly versus burnup will be used for the calculated reactivity uncertainty.

To determine the amount of boron credit required for the uncertainty in the calculation of burnup, the burnup credit reactivity bias is determined for the highest burnup requirement from the fuel storage curves for each region. SIMULATE-3 is then run to iterate on the boron concentration until the $k_{eff}$ is equal to the $k_{eff}$ with no boron, less the burnup credit reactivity bias.

The uncertainty on measured burnup is 4%. This is the measurement uncertainty applied to the 2-D power distribution ($F_{DH}$). This is conservative because the burnup is simply the power distribution integrated over time. Thus, to assume a burnup uncertainty of 4% is to assume the measured power distribution was low by 4% for its entire depletion history, when in reality it is low at times and high at other times.

To determine the amount of boron credit required for the measurement uncertainty on burnup, the highest burnup requirement from the fuel storage curves for each region is determined. The highest burnup requirement is then reduced by 4%. SIMULATE-3 is then run to iterate on the boron concentration until the $k_{eff}$ with 4% reduced burnup is equal to the $k_{eff}$ with the highest burnup (i.e. not reduced) and no boron.

Since the criticality calculations used to define the spent fuel storage limits are performed in 2-dimensions, a flat axial burnup distribution is inherent in the 2-D modeling. An analysis performed to study the effect of a 3-D burnup distribution determined that ignoring the effect of the axial variation in burnup on the criticality calculation becomes non-conservative as burnup increases. This analysis determined biases for each sub-region as a function of enrichment and burnup to be applied to account for the potential non-conservatism from not modeling the axial burnup distribution. The axial burnup distribution bias is then interpolated to the appropriate burnups of the assemblies in the specific problem.

To determine the amount of boron credit required to properly account for the axial burnup distribution, the axial burnup distribution bias is determined for the highest burnup requirements from the fuel storage curves for each region. SIMULATE is then run to iterate on the boron concentration until the $k_{eff}$ is equal to the $k_{eff}$ with no boron, less the axial burnup distribution bias.

For IFBA credit, the uncertainties associated with this reactivity equivalencing method are as follows:

| IFBA Credit Uncertainties |
|---|
| Manufacturing uncertainty |
| Calculational uncertainty |

The manufacturing uncertainty applied is a 5% decrease in the $B_{10}$ loading on the IFBA rods. To determine the amount of boron credit needed for the manufacturing uncertainty on IFBA rods, the highest number of IFBA rods required for storage is determined. CASMO-3 is then run to calculate the $k_{eff}$ with $B_{10}$ loading reduced by 5%. The boron concentration is iterated on until the $k_{eff}$ with the reduced $B_{10}$ loading is equal to the $k_{eff}$ with the normal loading and no boron.

The calculational uncertainty applied is a 10% decrease in the number of IFBA rods. To determine the amount of boron credit needed for the calculational uncertainty on IFBA rods, the highest number of IFBA rods required for storage is determined.

In this case, the IFBA requirements for 4.75 w/o fuel are interpolated from the previous IFBA results to determine a specific number of IFBA rods required, instead of one of the discrete number of IFBA rod configurations available. This specific number of IFBA rods is reduced by 10% and then rounded down to the nearest number of IFBA rods available. CASMO-3 is then run to calculate the $k_{eff}$ with this number of IFBA rods. The boron concentration is iterated on until the $k_{eff}$ with the reduced number of IFBA rods is equal to the no boron 95/95 maximum design $k_{eff}$.

Note that the IFBA credit uncertainties are only calculated for restricted storage in Region 1A since IFBA credit is not used for any other storage limits.

The boron credit requirements are summarized in Table 11.

### 3.3 New Fuel Storage Vault Analysis

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 $k_{eff}$ be maintained at less than or equal to 0.95 under fully flooded conditions and less than or equal to 0.98 assuming optimum moderation. Analysis used to determine $k_{eff}$ 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 enrichment. 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 base 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.

KENO-Va was used to calculate the $k_{eff}$ for 4.75 %U-235 nominal enrichment 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.

The following assumptions are used in the new fuel storage vault criticality analysis.

1. All fuel designs used, or planned for use, at McGuire were

analyzed. This included Westinghouse Standard (STD), Optimized (OFA) and Performance Plus (PF+) and Framatome Mark BW (MkBW) fuel designs.

2. All calculations are 3-D. The upper and lower fuel assembly nozzles are ignored.

3. All fuel is fresh unirradiated.

4. No credit is taken for the spacer grid material.

The calculated worst-case $k_{eff}$s for fully flooded and optimum moderation conditions for a fuel assembly with the maximum nominal enrichment of 4.75 %U-235 are:

Fully Flooded Maximum $k_{eff}$ = 0.9433
Optimum Moderation Maximum $k_{eff}$ = 0.9759

These values were for the Westinghouse Performance Plus fuel design which was the most reactive of all fuel types analyzed. 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 equal to 0.98 under optimum moderator conditions and less than or equal to 0.95 under fully flooded conditions. The analytical results shown above indicate that these criteria have been met.

3.4 Conditions Outside the Storage Rack

This section briefly describes the evaluation of the reactivity conditions of fuel located anywhere outside of the storage rack.

Fuel is first received in shipping containers approved for use under 10CFR Part 71 and need not be considered any further.

After the fuel is received it may be loaded into the new fuel storage vault which is discussed in Section 3.3.

The fuel is transferred from the new fuel vault into a new fuel elevator where it is lowered into the spent fuel pool such that the fuel handling crane can access it to place it in a storage cell. The most limiting condition from a criticality standpoint during this process is the fuel assembly in water with no poison. As discussed in Section 3.1, $k_{eff}$ must be less than 1.0 with no boron. This condition has been analyzed and it was determined that it would require a fresh fuel enrichment much greater than 5.0 w/o to approach a $k_{eff}$ of 1.0 for a single assembly surrounded by water. As discussed in Section 3.2, $k_{eff}$ must be less than or equal to 0.95 with credit for soluble boron. KENO is run to iterate on the boron concentration to determine the required boron to maintain $k_{eff} \leq 0.95$. To simplify this calculation, the calculation is performed at 4.80 w/o, instead of 4.75 w/o and all other fuel parameter uncertainties are neglected except the method bias and uncertainty determined in Table 2. The boron credit requirements for a single assembly in water are compared to the boron requirements determined as described in Section 3.2 and the more restrictive of the two will is used. This is because the boron requirements for the single assembly in water are independent of the boron requirements in Section 3.2. As can be seen from the results in Table 11, the single assembly in water case is well bounded by the boron credit required from Section 3.2.

The fuel is stored in the spent fuel storage cell until it is ready to be loaded into the reactor. At that point, the fuel handling crane moves the assembly into the upender, where it is then lowered to a horizontal position for transfer into the reactor building via the fuel transfer tubes. While the upender and fuel handling crane contain some amount of steel, and hence poison material, these conditions are bounded by the single assembly in water case.

Another possible location of fuel is in any reconstitution or inspection equipment. Criticality considerations for these scenarios are addressed by a 50.59 evaluation covering the use of the equipment for the intended purpose. Also included in this would be storage of failed fuel in special canisters or racks.

The only other possible places to have a fuel assembly would be as a result of an accident, i.e. dropping an assembly where it is not supposed to be. These conditions are covered by either the single assembly in water condition described in this section, or in Section 4.0.

Therefore, all possible locations of a fuel assembly inside the McGuire Nuclear Station are acceptable for up to and including 4.75 w/o for all analyzed fuel designs.

## 4.0 ACCIDENT CONDITIONS

As part of the criticality analysis for the McGuire spent fuel pools, abnormal and accident conditions are considered to verify that acceptable criticality margin is maintained for all conditions. Most accident conditions will not result in an increase in $k_{eff}$ of the rack. However, accidents can be postulated which would increase the reactivity of the spent fuel pool. These accidents must be analyzed to verify acceptable criticality safety margin exists. Since boron is used to compensate for reactivity increases as a result of postulated accidents, acceptable criticality safety margin exists if the total boron requirements are less than the normal concentration in the storage pool water.

The most severe accident in terms of criticality would be the misloading of an assembly; in particular, misloading the highest reactive assembly allowed in the pool in place of the lowest reactive assembly. This accident would be the substitution of a fresh 4.75 w/o assembly for a required filler assembly.

Since the SIMULATE-3 models for the McGuire storage racks consist of a 2x2 array reflected with periodic boundary conditions, the substitution of a fresh 4.75 w/o assembly for a required filler assembly will be extremely conservative since this accident condition will be infinitely reflected. A more realistic representation of this accident would be to model a larger array, and misloading a single assembly near the center of this array. However, since substantial criticality margin exists, the overly conservative 2x2 array will be sufficient.

Other accidents which could have an impact on reactivity in the spent fuel pool are those that affect the water temperature of the spent fuel pool. Accidents could be postulated which would either increase or decrease the temperature of the spent fuel pool. Therefore, to bound the range of temperatures of the spent fuel pool water, the accident analysis considers water temperatures of 32 and 212 $^{\circ}$F.

The above accident conditions are analyzed and the boron concentration is iterated upon until the calculated $k_{eff}$ is less than the no boron 95/95 maximum design $k_{eff}$. This boron concentration, combined with the boron concentration for boron credit 95/95 $k_{eff}$ from Section 3.2 represents the total credit for boron that is required for accident conditions. This total boron requirement must be less than the normal spent fuel pool boron concentration.

Note that by combining the boron required for accidents with the boron required to maintain $k_{eff} \leq 0.95$ (i.e. the boron credit 95/95 maximum design $k_{eff}$), the accident conditions are imposed on top of the dilution accident for the total boron requirements. However, accident conditions are not assumed with no boron conditions. This is consistent with previous criticality analysis methodology where the double contingency principle is applied for accidents. The double contingency principle allows credit for soluble boron under other abnormal or accident conditions, since only a single accident need be considered at one time and to not assume the presence of some boron would be a second unlikely event. The difference with the boron credit methodology is that, for added assurance that sufficient criticality safety margin exists, the dilution of the pool with perfect mixing to 937 ppm is assumed to be a credible event.

The additional boron credit requirements for accident conditions are summarized in Table 11.

## 5.0 BORON CREDIT SUMMARY

This analysis takes partial credit for soluble boron in the spent fuel pool for both normal and accident conditions. Boron credit is used to compensate for uncertainties related to reactivity equivalencing and accident conditions. The total boron credit requirements for each region are shown in Table 11. The total boron credit requirements for the entire McGuire spent fuel pool are then the highest values from all regions as follows:

| | Boron Credit Required | Boron Available |
|---|---|---|
| Normal Conditions | 850 | 937[1] |
| Accident Conditions | 1470 | 2675[2] |

[1] - From dilution analysis
[2] - current limit specified in the Core Operating Limits Report

## 6.0 REGION INTERFACE RESTRICTIONS

Fuel will be stored in four regions of the spent fuel pool according to three different loading configurations. The boundary conditions between these configurations are analyzed to assure that the storage configurations at the boundary do not cause an increase in the nominal $k_{eff}$ above the design criteria limit on $k_{eff}$ for the individual regions. This analysis is performed to determine if there is a need for new administrative restrictions at the boundaries. The results of this analysis yield the following region interface restrictions.

**Region Interface Restrictions**

| | | |
|---|---|---|
| Region 1A | Unrestricted Storage | No restrictions |
| Region 1A | Restricted Storage | Any Restricted Region 1A Storage Area row bounded by any other storage area shall contain a combination of restricted fuel assemblies and filler locations such that no restricted fuel assemblies are adjacent to each other. Example: In Figure 3, row 1 or column 1 can <u>not</u> be adjacent to another storage area, but row 4 column 4 can be. |
| Region 1B | Unrestricted Storage | No restrictions |
| Region 1B | Restricted Storage | Any Restricted Region 1B Storage Area must be separated from any other storage area by at least one row of 1B Filler Locations or empty cells, at all boundaries between storage regions. |
| Region 1B | Checkerboard Storage | Any Checkerboard Region 1B Storage Area must be separated from any other storage area by at least one row of empty cells, at all boundaries between storage regions. |
| Region 2A | Unrestricted Storage | No restrictions |
| Region 2A | Restricted Storage | At least three of the four faces of each Restricted Fuel assembly must be adjacent to a 2A Filler Fuel assembly, an empty cell, or the pool wall, at all boundaries between storage regions. |
| Region 2A | Checkerboard Storage | At least three of the four faces of each Checkerboard Fuel assembly must be adjacent to an empty cell or the pool wall, at all boundaries between storage regions. |
| Region 2B | Unrestricted Storage | No restrictions |
| Region 2B | Restricted Storage | Any Restricted 2B Storage Area row bounded by any other storage area shall contain only filler locations arranged such that no Restricted Fuel assemblies are adjacent to any other fuel except Region 2B Filler Locations. Example: In Figure 5, row 1 or column 1 can <u>not</u> be adjacent to another storage area, but row 4 or column 4 can be. |

| | | |
|---|---|---|
| Region 2B | Checkerboard Storage | Any Checkerboard Region 2B Storage Area row bounded by any other storage area shall contain only empty cells arranged such that no Checkerboard Fuel assemblies are adjacent to any fuel. Example: In Figure 7, row 1 or column 1 can not be adjacent to another storage area, but row 4 or column 4 can be. |

## 7.0 SUMMARY OF RESULTS

The results of the criticality analysis for the McGuire spent fuel storage racks indicate that the acceptance criteria for criticality is met; that is $k_{eff} \leq 0.95$ including uncertainties. The two region rack design is subdivided within each region for cells with credit for Boraflex and cells without credit for Boraflex. This analysis takes credit for soluble boron, partial credit for Boraflex in Regions 1A and 2A, no credit for Boraflex in Regions 1B and 2B, credit for burnup and credit for IFBA rods. Each of the four regions has two storage configurations, Unrestricted and Restricted storage. Three regions (Regions 1B, 2A and 2B) have an additional Checkerboard configuration that allows the most reactive fuel to be stored.

The spent fuel storage limits are summarized in Tables 6 through 10 and Figures 3 through 9.

The total boron credit requirements for these configurations in all regions are 850 ppm for normal conditions and 1470 ppm for accident conditions.

Also, the acceptability of storing the new Westinghouse Performance Plus fuel design in the new fuel storage vaults is verified.

## 8.0 REFERENCES

8.1 "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," WCAP-14416-NP-A, Westinghouse Commercial Nuclear Fuel Division, Revision 1, November, 1996.

8.2 "Issuance of Amendments - McGuire Nuclear Station, Units 1 and 2," Amendment Nos. 159 and 141 to Facility Operating Licenses NPF-9 and NPF-17, U.S. Nuclear Regulatory Commission, November 6, 1995.

8.3 Baldwin, Hoovler, Eng, and Welfare, "Critical Experiments Supporting Close Proximity Water Storage of Power Reactor Fuel", B&W-1484-7, 7/79.

8.4 Beirman, S.R., Clayton, E.D., "Criticality Experiments with Subcritical Clusters of 2.35 and 4.31 wt% 235U Enriched UO2 Rods in Water at a Water to Fuel Volume Ratio of 1.6" PNL-3314, July 1980.

8.5 Beirman, S.R. , et al, "Critical Separation Between Subcritical Clusters of 2.35 wt% 235U Enriched UO2 Rods in Water with Fixed Neutron Poisons" PNL-2438, October 1977.

8.6 Beirman, S.R., "Criticality Experiments to Provide Benchmark Data on Neutron Flux Traps" PNL-6205, June 1988.

Table 1

CASMO-3/TABLES-3/SIMULATE-3

Benchmarking Results

| Core | Soluble Boron | Moderator Temp | Separation Spacing (cm) | Poison Sheet (%B) | $k_{eff}$ calc | $k_{eff}$ meas | Bias |
|---|---|---|---|---|---|---|---|
| 2 | 1037 | 18.5 | 0 | n/a | 1.00271 | 1.0001 | -0.00261 |
| 3 | 764 | 18 | 1.636 | n/a | 1.00319 | 1.0000 | -0.00319 |
| 9 | 0 | 17.5 | 6.544 | n/a | .99908 | 1.0030 | 0.00392 |
| 10 | 143 | 24.5 | 4.908 | n/a | .99795 | 1.0001 | 0.00215 |
| 11 | 514 | 26 | 1.636 | SS | 1.00493 | 1.0000 | -0.00493 |
| 13 | 15 | 20 | 1.636 | 1.614 | 1.00914 | 1.0000 | -0.00914 |
| 14 | 92 | 18 | 1.636 | 1.257 | 1.00451 | 1.0001 | -0.00441 |
| 15 | 395 | 18 | 1.636 | 0.401 | .99608 | 0.9988 | 0.00272 |
| 17 | 487 | 17.5 | 1.636 | 0.242 | .99889 | 1.0000 | 0.00111 |
| 19 | 634 | 17.5 | 1.636 | 0.1 | 1.00003 | 1.0002 | 0.00017 |
| | | | | avg $k_{eff}$calc | 1.00165 | st.dev calc | 0.00412 |
| | | | | avg $k_{eff}$ meas | 1.00023 | avg bias | -0.00142 |

CASMO-3/TABLES-3/SIMULATE-3 Methodology Bias = -0.00142

CASMO-3/TABLES-3/SIMULATE-3 Methodology Uncertainty = 0.01199

Table 2

KENO-Va

Benchmarking Results

| Report | Exp. Number | Calculated $k_{eff}$ | std dev | Report | Exp. Number | Calculated $k_{eff}$ | std dev |
|---|---|---|---|---|---|---|---|
| PNL-3314 | 043 | 0.99991 | 0.00295 | PNL-3314 | 085 | 0.98979 | 0.00354 |
| PNL-3314 | 045 | 0.9984 | 0.00335 | PNL-3314 | 094 | 0.99568 | 0.00383 |
| PNL-3314 | 046 | 0.9999 | 0.0033 | PNL-3314 | 095 | 0.99914 | 0.004 |
| PNL-3314 | 047 | 1.00532 | 0.00346 | PNL-3314 | 096 | 0.99908 | 0.00349 |
| PNL-3314 | 048 | 1.00083 | 0.00326 | PNL-3314 | 097 | 0.99731 | 0.00342 |
| PNL-3314 | 04c | 0.99727 | 0.00317 | PNL-3314 | 098 | 0.99494 | 0.00353 |
| PNL-3314 | 051 | 1.00114 | 0.00392 | PNL-3314 | 100 | 0.99621 | 0.00378 |
| PNL-3314 | 053 | 0.99105 | 0.0035 | PNL-3314 | 101 | 0.99799 | 0.00391 |
| PNL-3314 | 055 | 0.99502 | 0.00409 | PNL-3314 | 105 | 0.99911 | 0.00339 |
| PNL-3314 | 056 | 0.99249 | 0.0038 | PNL-3314 | 106 | 0.99323 | 0.00353 |
| PNL-3314 | 057 | 0.99603 | 0.00317 | PNL-3314 | 107 | 0.99812 | 0.00302 |
| PNL-3314 | 058 | 0.99613 | 0.00321 | PNL-3314 | 131 | 0.99708 | 0.00379 |
| PNL-3314 | 059 | 0.99233 | 0.00377 | PNL-3314 | 996 | 1.0115 | 0.00304 |
| PNL-3314 | 060 | 0.99657 | 0.00362 | PNL-3314 | 997 | 1.00775 | 0.00305 |
| PNL-3314 | 061 | 0.99331 | 0.00371 | PNL-2438 | 005 | 0.9923 | 0.00348 |
| PNL-3314 | 062 | 0.9954 | 0.00418 | PNL-2438 | 014 | 0.99212 | 0.00321 |
| PNL-3314 | 064 | 0.98736 | 0.00351 | PNL-2438 | 015 | 0.99207 | 0.00301 |
| PNL-3314 | 065 | 0.99728 | 0.00392 | PNL-2438 | 021 | 0.99119 | 0.00302 |
| PNL-3314 | 066 | 0.9942 | 0.00374 | PNL-2438 | 026 | 0.99218 | 0.00314 |
| PNL-3314 | 067 | 0.99153 | 0.00374 | PNL-2438 | 027 | 0.99396 | 0.00312 |
| PNL-3314 | 068 | 0.99169 | 0.00333 | PNL-2438 | 028 | 0.99092 | 0.00322 |
| PNL-3314 | 069 | 0.99684 | 0.00396 | PNL-2438 | 029 | 0.99366 | 0.00319 |
| PNL-3314 | 06d | 1.00645 | 0.004 | PNL-2438 | 034 | 0.99596 | 0.00323 |
| PNL-3314 | 070 | 0.98921 | 0.00369 | PNL-2438 | 035 | 0.98911 | 0.00317 |
| PNL-3314 | 071 | 0.99405 | 0.00342 | PNL-6205 | 214 | 0.99117 | 0.00353 |
| PNL-3314 | 072 | 0.98865 | 0.00356 | PNL-6205 | 223 | 0.99726 | 0.0038 |
| PNL-3314 | 073 | 0.98801 | 0.00343 | PNL-6205 | 224 | 0.99329 | 0.00388 |
| PNL-3314 | 083 | 0.99043 | 0.00341 | PNL-6205 | 229 | 1.00119 | 0.00355 |
| PNL-3314 | 084 | 0.99366 | 0.00364 | PNL-6205 | 230 | 1.00031 | 0.00406 |

Average $k_{eff}$ = 0.99559

KENO-Va Methodology Bias = 0.00441

KENO-Va Methodology Uncertainty = 0.00739

Table 3
CASMO-3 / SIMULATE-3 / KENO Va Comparisons

| Rack Region | Fuel Enrichment | Fuel Type | CASMO $k_{eff}$ | Simulate $k_{eff}$ | KENO $k_{eff}$ |
|---|---|---|---|---|---|
| MNS Region 1A (25% of original Boraflex) | 4.0 | mbw | .97661 | .976666 | .96827 |
| MNS Region 1B (No Boraflex) | 4.0 | mbw | 1.18568 | 1.185535 | 1.17930 |
| MNS Region 2A (40% of original Boraflex) | 1.4 | mbw | .94030 | .94033 | .93791 |
| MNS Region 2B (No Boraflex) | 1.4 | mbw | 1.06701 | 1.06701 | 1.06233 |

Table 4
CASMO / SIMULATE
No Boron Biases and Uncertainties for Fresh Fuel

| Bias or Uncertainty | Region 1A | Region 1B | Region 2A | Region 2B |
|---|---|---|---|---|
| Methodology Bias* | -0.00142 | -0.00142 | -0.00142 | -0.00142 |
| Boraflex Width Shrinkage Bias | 0.005405 | 0 | 0.00202 | 0 |
| Self-Shielding Bias | 0.002141 | 0 | 0.000712 | 0 |
| 3 Dimensional Bias* | -0.00158 | -0.00252 | -0.00202 | -0.00295 |
| 95/95 Methodology Uncertainty | 0.01199 | 0.01199 | 0.01199 | 0.01199 |
| Boraflex Axial Shrinkage Uncertainty | 0.002595 | 0 | 0.00010 | 0 |
| Mechanical Uncertainty | 0.015923 | 0.018729 | 0.00804 | 0.010993 |
| Combined Bias and Uncertainty | 0.027647 | 0.022238 | 0.01717 | 0.016267 |

| | | | | |
|---|---|---|---|---|
| No Boron 95/95 Maximum Design $k_{eff}$ | 0.972353 | 0.977762 | 0.98283 | 0.983733 |

Combined Bias and Uncertainty:

$$\Delta k = \Delta k_{MethBias} + \Delta k_{Width} + \Delta k_{SelfShielding} + \Delta k_{3\ Dimensional} + \sqrt{\Delta k^2_{MethUnc} + \Delta k^2_{Axial} + \Delta k^2_{MechUnc}}$$

* Negative bias conservatively ignored

For KENO-Va calculations, the above methodology bias and uncertainty are replaced with the KENO-Va methodology bias and uncertainty (Table 2) and the KENO-Va calculated uncertainty is included under the radical.

Table 5
CASMO / SIMULATE
Boron Credit Biases and Uncertainties for Fresh Fuel

| Bias or Uncertainty | Region 1A | Region 1B | Region 2A | Region 2B |
|---|---|---|---|---|
| Methodology Bias* | -0.00142 | -0.00142 | -0.00142 | -0.00142 |
| Boraflex Width Shrinkage Bias | 0.005405 | 0 | 0.00202 | 0 |
| Self-Shielding Bias | 0.002141 | 0 | 0.000712 | 0 |
| 3 Dimensional Bias* | -0.00158 | -0.00252 | -0.00202 | -0.00295 |
| 95/95 Methodology Uncertainty | 0.01199 | 0.01199 | 0.01199 | 0.01199 |
| Boraflex Axial Shrinkage Uncertainty | 0.002595 | 0 | 0.00010 | 0 |
| Mechanical Uncertainty | 0.015912 | 0.019684 | 0.008911 | 0.010922 |
| Combined Bias and Uncertainty | 0.027638 | 0.023049 | 0.01767 | 0.016266 |

| | | | | |
|---|---|---|---|---|
| Boron Credit 95/95 Maximum Design $k_{eff}$ | 0.922362 | 0.926951 | 0.93233 | 0.933734 |

Combined Bias and Uncertainty:

$$\Delta k = \Delta k_{MethBias} + \Delta k_{Width} + \Delta k_{SelfShielding} + \Delta k_{3\ Dimensional} + \sqrt{\Delta k^2_{MethUnc} + \Delta k^2_{Axial} + \Delta k^2_{MechUnc}}$$

* Negative bias conservatively ignored

Table 6
Summary of Maximum Fresh Fuel Enrichment Limits (w/o U-235)

| Type of Storage | Region 1A | Region 1B | Region 2A | Region 2B |
|---|---|---|---|---|
| Unrestricted | 3.78 | 1.78 | 1.50 | 1.11 |
| Restricted | 4.75 | 2.20 | 1.80 | 1.22 |
| Filler | 1.76 | 1.44 | 1.15 | 1.08 |
| Checkerboard | N/A | 4.75 | 4.75 | 4.75 |

Table 7
Minimum Qualifying Burnup versus Initial Enrichment
For Unrestricted Storage

| Region 1A | | Region 1B | | Region 2A | | Region 2B | |
|---|---|---|---|---|---|---|---|
| Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) |
| 3.78 | 0.00 | 1.78 | 0.00 | 1.50 | 0.00 | 1.11 | 0.00 |
| 4.00 | 1.58 | 2.00 | 3.96 | 2.00 | 10.50 | 2.00 | 21.58 |
| 4.50 | 4.92 | 2.50 | 11.35 | 2.50 | 17.97 | 2.50 | 29.00 |
| 4.75 | 6.66 | 3.00 | 17.61 | 3.00 | 24.49 | 3.00 | 35.69 |
| | | 3.50 | 23.35 | 3.50 | 30.55 | 3.50 | 41.97 |
| | | 4.00 | 28.86 | 4.00 | 36.25 | 4.00 | 47.90 |
| | | 4.50 | 34.10 | 4.50 | 41.71 | 4.50 | 53.57 |
| | | 4.75 | 36.67 | 4.75 | 44.39 | 4.75 | 56.33 |

Table 8
Minimum Qualifying Burnup versus Initial Enrichment
For Restricted Storage

| Region 1A | | Region 1B | | Region 2A | | Region 2B | |
|---|---|---|---|---|---|---|---|
| Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) |
| 4.75 | 0.00 | 2.20 | 0.00 | 1.80 | 0.00 | 1.22 | 0.00 |
| | | 2.50 | 3.91 | 2.00 | 3.70 | 2.00 | 17.55 |
| | | 3.00 | 9.65 | 2.50 | 10.30 | 2.50 | 24.73 |
| | | 3.50 | 15.04 | 3.00 | 16.10 | 3.00 | 31.31 |
| | | 4.00 | 19.87 | 3.50 | 21.70 | 3.50 | 37.40 |
| | | 4.50 | 24.68 | 4.00 | 27.00 | 4.00 | 43.15 |
| | | 4.75 | 27.01 | 4.50 | 32.10 | 4.50 | 48.65 |
| | | | | 4.75 | 34.50 | 4.75 | 51.33 |

Table 9
Minimum Qualifying Burnup versus Initial Enrichment
For Filler Assemblies

| Region 1A | | Region 1B | | Region 2A | | Region 2B | |
|---|---|---|---|---|---|---|---|
| Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) | Initial Enrichment (w/o U-235)) | Minimum Burnup (GWD/MTU) |
| 1.76 | 0.00 | 1.44 | 0.00 | 1.15 | 0.00 | 1.08 | 0.00 |
| 2.00 | 5.12 | 2.00 | 12.68 | 2.00 | 20.00 | 2.00 | 23.14 |
| 2.50 | 13.57 | 2.50 | 20.17 | 2.50 | 27.80 | 2.50 | 30.59 |
| 3.00 | 19.80 | 3.00 | 27.03 | 3.00 | 34.60 | 3.00 | 37.42 |
| 3.50 | 25.85 | 3.50 | 33.35 | 3.50 | 41.10 | 3.50 | 43.74 |
| 4.00 | 31.50 | 4.00 | 39.33 | 4.00 | 47.20 | 4.00 | 49.72 |
| 4.50 | 36.93 | 4.50 | 45.07 | 4.50 | 53.10 | 4.50 | 55.49 |
| 4.75 | 39.54 | 4.75 | 47.89 | 4.75 | 55.90 | 4.75 | 58.33 |

Table 10
Summary of IFBA Credit Requirements

| Number of IFBA Rods | Maximum Fresh Fuel Enrichment For Unrestricted Storage |
|---|---|
| 0 | 3.78 |
| 16 | 4.22 |
| 32 | 4.56 |
| 48 | 4.89 |

Table 11
Summary of Boron Credit Requirements

| | Unrestricted | | | | Restricted w/ Filler | | | |
|---|---|---|---|---|---|---|---|---|
| | 1A | 1B | 2A | 2B | 1A | 1B | 2A | 2B |
| k-eff $\leq$ 0.95 | | | | | | | | |
| Boron required for k-eff $\leq$ 0.95 | 310 | 160 | 290 | 160 | 330 | 160 | 290 | 160 |
| Reactivity Equivalencing | | | | | | | | |
| Boron required for bu unc | 20 | 50 | 120 | 120 | 30 | 50 | 130 | 120 |
| Boron required for measured burnup | 20 | 40 | 120 | 100 | 10 | 40 | 110 | 100 |
| Boron required for axial burnup | 0 | 70 | 310 | 350 | 70 | 90 | 320 | 350 |
| Boron required for IFBA manuf unc | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Boron required for IFBA calc unc | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Accident conditions | | | | | | | | |
| Boron required for misload | 300 | 360 | 580 | 740 | 300 | 360 | 580 | 740 |
| Boron required for abnormal heat load | 0 | 20 | 0 | 0 | 0 | 20 | 0 | 0 |
| Boron required for emergency makeup | 10 | 0 | 10 | 0 | 10 | 0 | 10 | 0 |
| Boron required for single assy in water | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 |
| Total Boron Credit Required w/o Accidents | 440 | 320 | **840** | 730 | 440 | 340 | **850** | 730 |
| | | | | | | | | |
| Total Boron Credit Required with Accidents | 740 | 680 | 1420 | **1470** | 740 | 700 | 1430 | **1470** |

**Figure 1**
**McGuire Fuel Pool Layout with Region 1 Detail**

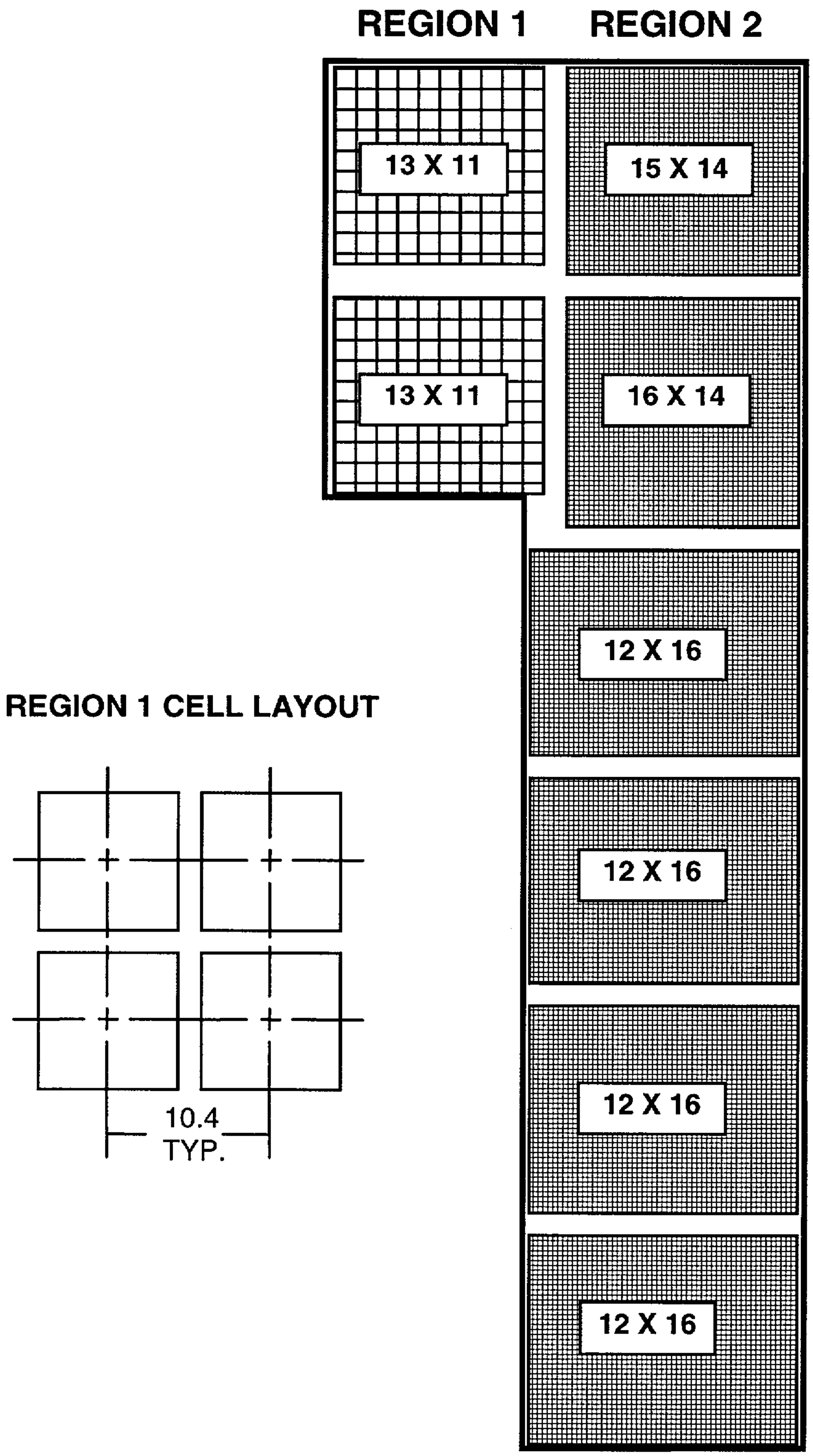


**Figure 2**
**McGuire Fuel Pool Layout with Region 2 Detail**

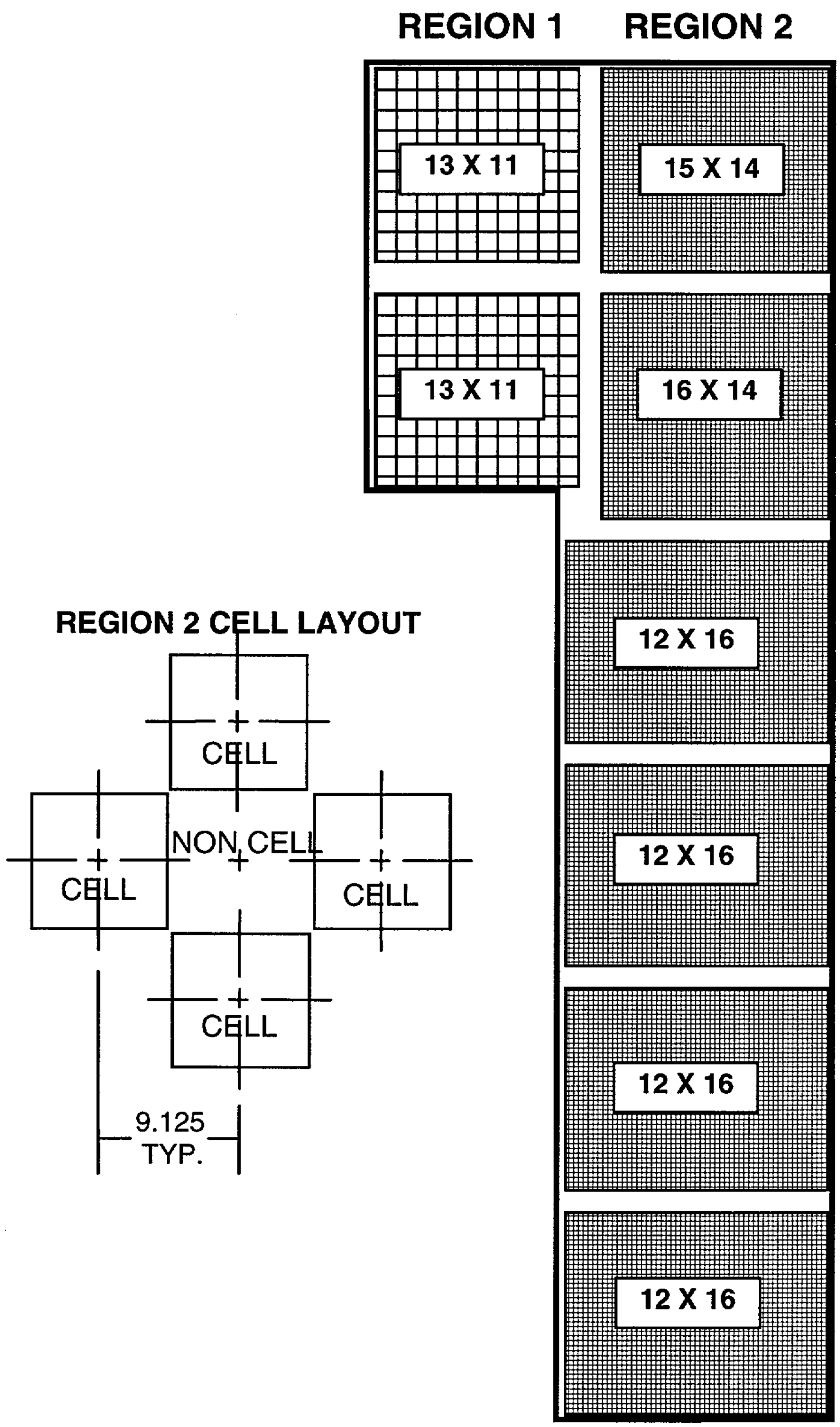


**Figure 3**
**3 out of 4 Restricted Storage Pattern for Region 1A**

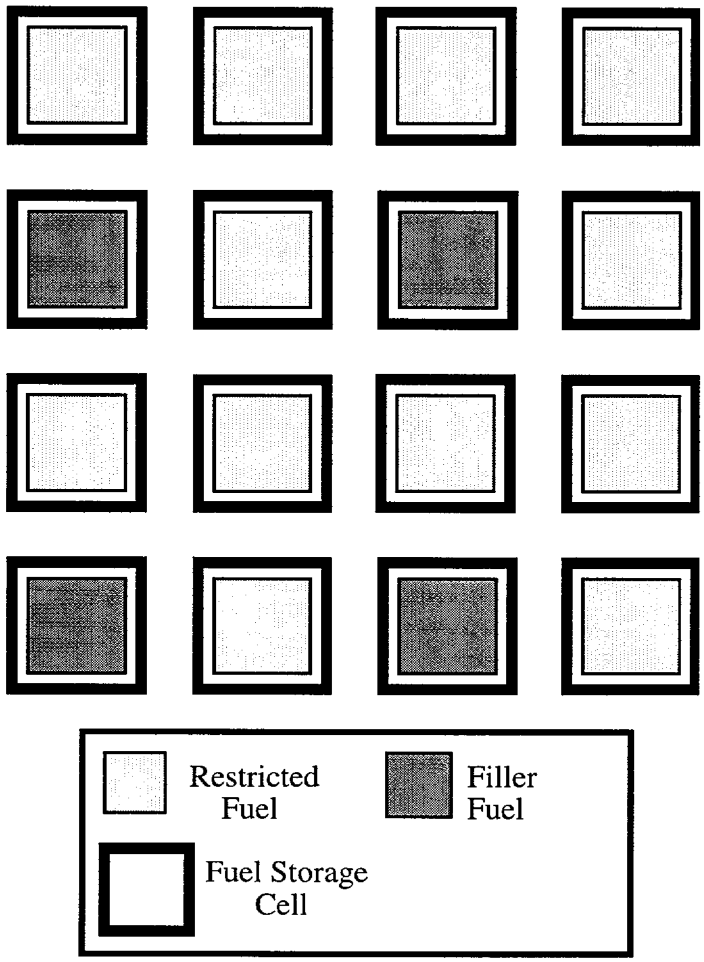


**Figure 4**
**2 out of 4 Restricted Storage Pattern for Regions 1B and 2A**

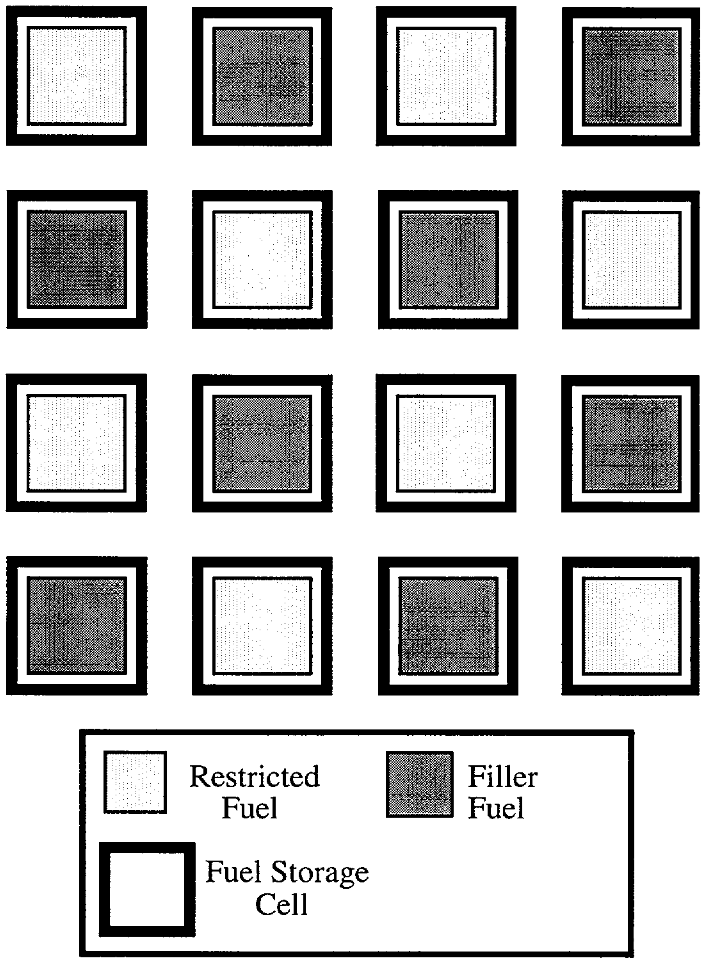


**Figure 5**
**1 out of 4 Restricted Storage Pattern for Region 2B**

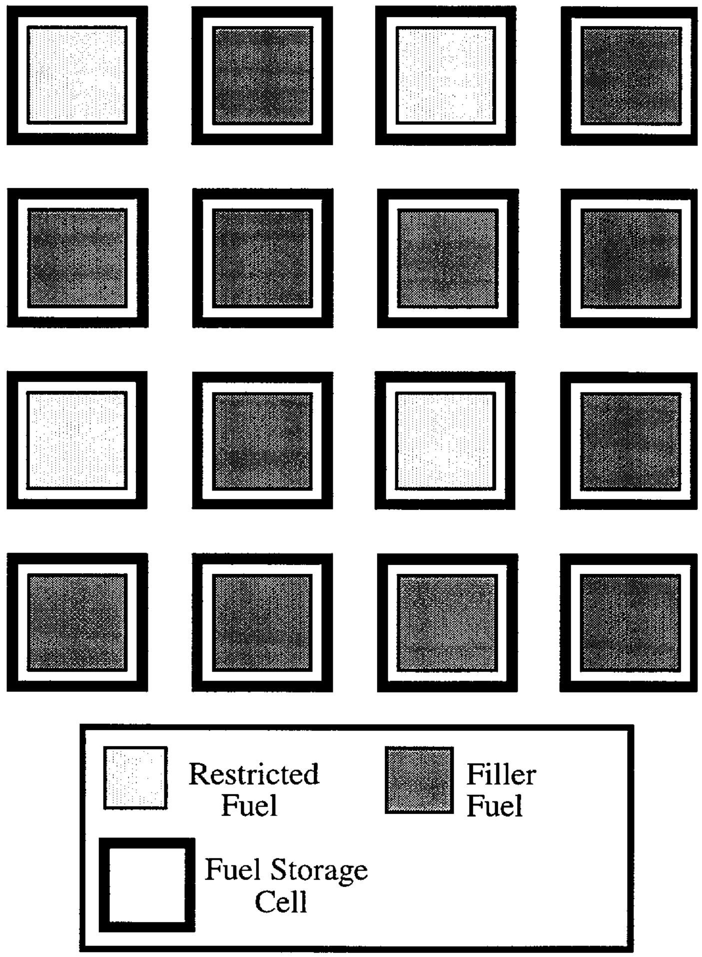


**Figure 6**
**2 out of 4 Checkerboard Storage Pattern for Regions 1B and 2A**

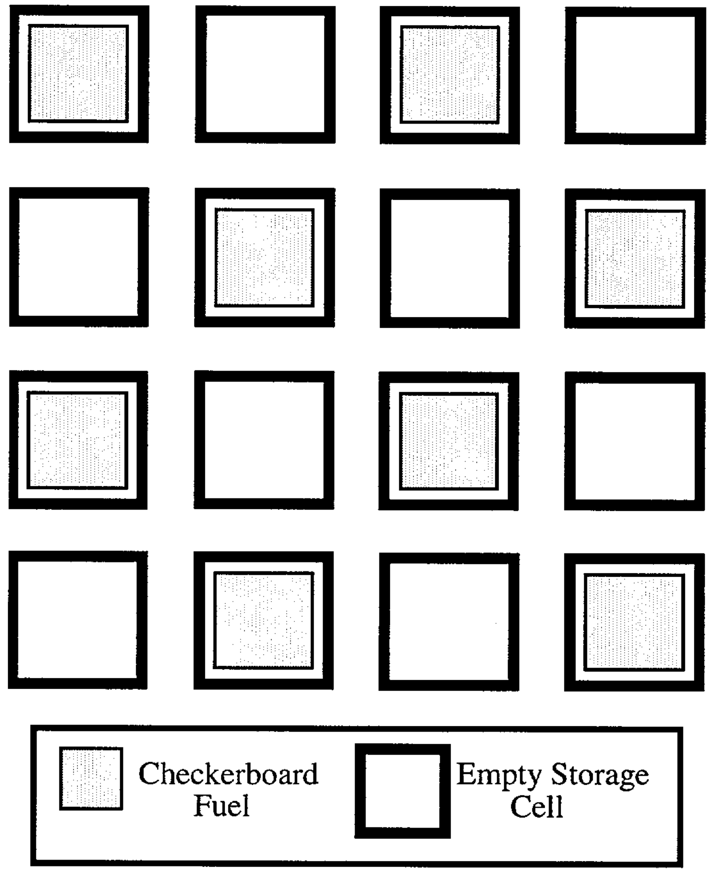


**Figure 7**
**1 out of 4 Checkerboard Storage Pattern for Region 2B**

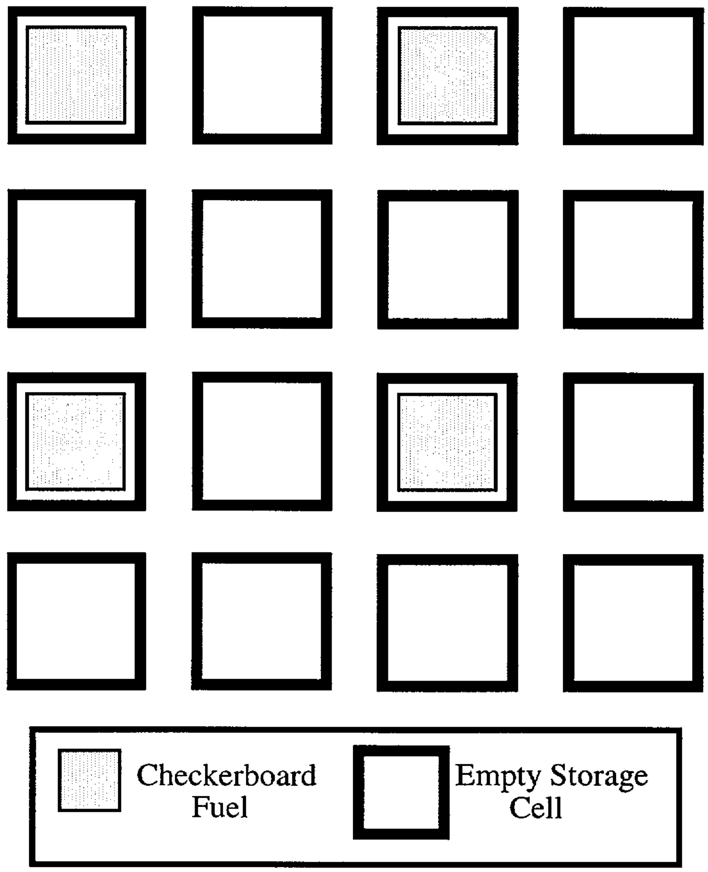


**Figure 8**
**McGuire Region 1A and 1B**
**Burnup versus Enrichment Limits**

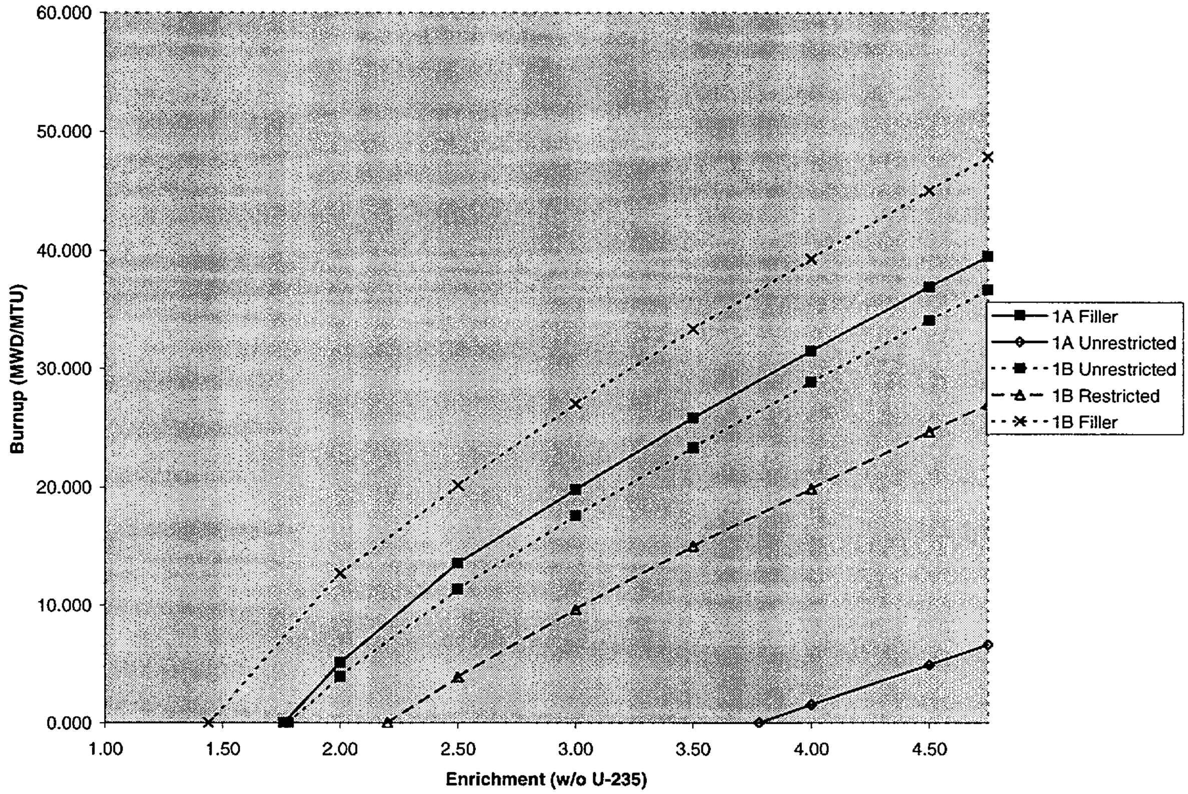
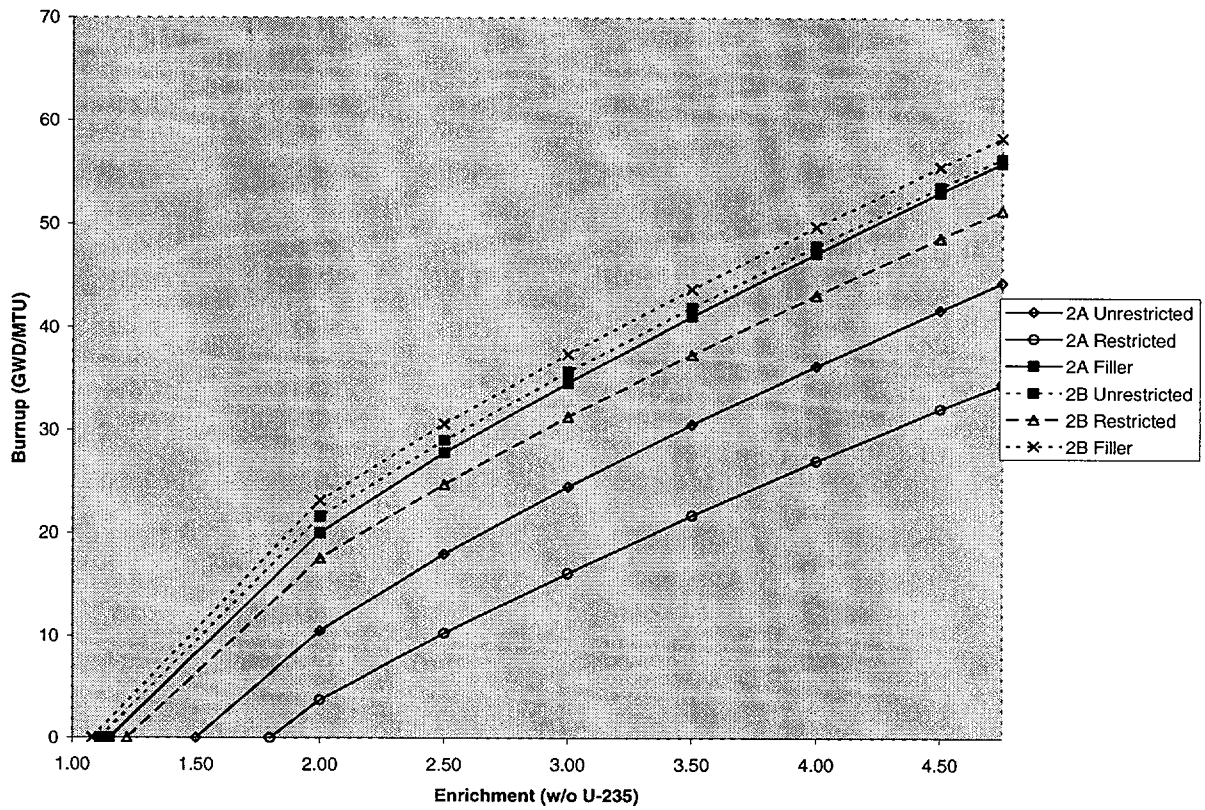


**Figure 9**
**McGuire Region 2A and 2B**
**Burnup versus Enrichment Limits**



# ATTACHMENT 7

# MCGUIRE NUCLEAR STATION
# BORAFLEX DEGRADATION MANAGEMENT

# MCGUIRE BORAFLEX DEGRADATION MANAGEMENT

## Table of Contents

## 1.0 BACKGROUND

A primary function of the spent fuel storage racks is to provide for safe storage of fuel assemblies in a borated water pool while preventing criticality. Criticality control is provided through the geometrical spacing of the fuel assemblies, use of a neutron poison material (Boraflex), and credit for soluble boron in the spent fuel pool water. Therefore, verification of the poison material composition and dimensions are important to maintaining the sub-critical margin to safety.

The Unit 1 racks were installed in January 1986, and the Unit 2 racks were installed in December 1984. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide neutron absorbing material. Fixed Boraflex neutron absorbing panels surround each storage cell on all four sides (except for peripheral locations.) The as-built Boraflex panels have a guaranteed minimum $^{10}B$ areal density of 0.02 $g/cm^2$ in Region 1 and 0.006 $g/cm^2$ in Region 2. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet which is spot welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex is contained in the plenum area between the storage tube and the wrapper plate.

Since the wrapper plate enclosure is not airtight, spent fuel pool water fills the volume of the plenum not taken by the Boraflex panel. It has been observed that after the Boraflex receives a high gamma dose from the spent fuel ($>10^{10}$ rads), the Boraflex can begin to degrade and dissolve in the wet environment. Thus, the poison material can be slowly removed as it is carried away from the plenum region by the spent fuel pool water, thereby reducing the poison worth of the Boraflex sheets.

The Boraflex degradation phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks" (Reference 6.1). Duke Energy responded by letters dated October 22, 1996; December 22, 1997; and December 31, 1998 (References 6.2 through 6.4). In these letters, Duke Energy, in addition to providing background information, committed to 1)performing a RACKLIFE assessment of the spent fuel pools, 2)demonstration of the EPRI Boron Areal Density Gage (BADGER) in-situ measurement, and 3)assessment of the storage rack reactivity. In the letter to the NRC dated December 31, 1998, Duke Energy committed to submitting a Technical Specification Change Request for McGuire in 1999 to define new spent fuel assembly storage limitations which utilize credit for soluble boron. As part of this request, Duke Energy committed to performing in-situ measurements at a frequency of three years, starting in 2000, to confirm the Boraflex levels assumed in the revised criticality analysis. This License Amendment Request was approved by the NRC on November 27, 2000.

## 2.0 PURPOSE

Key parameters used as input into the criticality analysis for the spent fuel storage racks (Attachment 6) are the Boraflex properties, including material composition and physical dimensions. The degradation mechanisms of Boraflex, including the gap formation, axial and width shrinkage of Boraflex induced by gamma irradiation, are accounted for in the criticality analysis as uncertainties. Uniform panel dissolution is accounted for in the Boraflex boron-10 ($^{10}B$) areal density, with panel designation provided in Selected Licensee Commitments 16.9.24 (Attachment 8). This attachment provides an assessment of the Boraflex in the McGuire spent fuel racks and the methodology for management of the degradation.

## 3.0 APPROACH

Duke Energy's preferred method to verify the amount of remaining $^{10}B$ areal density is through in-situ measurement, however, it is not feasible to measure each of the more than 3,000 Boraflex panels in each pool. Therefore, the results from in-situ measurements are used in conjunction with a computer program that predicts individual panel degradation. Currently the method of in-situ measurement of the panel average $^{10}B$ areal density is through BADGER measurements, and the computer program used to predict individual panel average degradation is RACKLIFE.

### 3.1 In-Situ Measurement (BADGER)

Northeast Technology Corporation (NETCO), under contract to the Electric Power Research Institute (EPRI), has developed the Boron-10 Areal Density Gage for Evaluating Racks (BADGER). This system is used to measure the $^{10}B$ areal density (expressed as grams of $^{10}B$ per $cm^2$) in spent fuel storage racks.

The BADGER system consists of a source head containing a $^{252}Cf$ source and a detector head containing BF-3 detectors that are lowered simultaneously into adjacent spent fuel storage cells. A stepper motor and winch attached to the fuel bridge auxiliary hoist allow the detector/source heads to be remotely located at desired elevations in the storage racks. The detector signals are fed into four pre-amplifiers and then to an electronics console that is positioned beside the pool. The signals are recorded on a computer that also controls the stepper motor for positioning of the detector/source heads.

The principle of BADGER is based on the measurement of thermal neutron attenuation by the Boraflex panel(s) between the source and detectors. The number of neutrons emitted by the $^{252}Cf$ source that reach the BF-3 detectors, is a function of the $^{10}B$ areal density in the Boraflex. The magnitudes of the detector signals, in turn, are a function of the $^{10}B$ areal density in the Boraflex panels. For panels with high density, the detector signals are low, whereas for low areal densities the signals are high.

The BADGER equipment is calibrated by means of a calibration cell that is similar in construction to the spent fuel storage cells and has two sides that represent both Region 1 (flux trap) and Region 2 (egg crate) racks. Each side has a sequence of Boraflex standards of varying known $^{10}B$ areal densities arranged axially, as well as some gaps of known size. At the beginning of a campaign, the BADGER probe is lowered into the calibration cell and both sides are scanned. The bottom of the calibration cell establishes a reference elevation datum during calibration. After scanning the calibration cell, BADGER is ready for measurement operations. No further calibration is required during the campaign unless excessive drift in the electronics was to occur.

The areal density of a Boraflex panel is determined by comparing the detector count rate through the panel to the count rates through panels of known areal density in the calibration cell. In a Boraflex panel that has thinned due to dissolution of the residual Boraflex matrix, a higher detector count rate is recorded. The amount of thinning of a panel in a thinned condition is determined by comparison with a fit of the standards in the calibration cell. To quantify the actual areal density of an irradiated panel in the racks that has undergone some dissolution, usually a relatively intact (e.g., unirradiated or low dose) panel in the racks of known areal density must be available to measure and compare against. This is to account for small but discernable differences between the calibration cell and the actual racks.

A Boraflex panel is measured in the following sequence. The probe is placed into two specific cells on either side of the Boraflex panel of interest and lowered to the bottom of the cell. A load sensor on the lift assembly provides indication of when the probe is fully inserted. The reference elevation datum is established at the bottom of the cell and all measurements of probe elevation are relative to this datum. (When analyzing the data the elevation is subsequently adjusted to be relative to the bottom of the Boraflex panel according to as-built manufacturing drawings.)

The entire panel is scanned with the heads being moved in two-inch increments from the bottom of the cell to the top. The active portion of the detectors is two inches so a scan measurement represents complete axial coverage of the panel. At each elevation, the counts of each detector are measured for a period depending on the source strength, and are recorded by the data-logging computer. As the scan proceeds, the measurement equipment operator monitors the CRT of the computer as the counts are plotted on the screen as a function of axial elevation. The operator monitors the elevation where elevated count rates could be indicative of low $^{10}B$ areal densities or gaps in the Boraflex panel. After the scan is completed, the BADGER heads are moved so that they are flush with the top of the cell. Measuring the BADGER elevation here provides and additional datum to measure elevation in the cell. After the elevation measurement is complete, the probes are moved out of the measured cells and to a new location for subsequent measurement. Measurements are performed at least every three years and may be more frequent based upon engineering judgment.

Panels selected for measurement are based upon RACKLIFE predictions of gamma dose absorption and the resulting Boraflex degradation. A total of 15 panels are typically chosen for each region of each pool. These panels cover the range from zero absorbed dose and zero degradation to the maximum absorbed dose and maximum degradation. Panels that exhibit the least degradation and the most degradation are always selected for measurement, and panels with the least absorbed gamma dose and most absorbed gamma dose are usually selected for measurement. A reason for not selecting these panels would be due to distance from other selected panels that would require a significant number of fuel moves. The remaining panels are selected with consideration of location in relation to other selected panels and the amount of Boraflex degradation. Panels are selected to cover the entire range of degradation with a slight preference of highly degraded panels.

After a measurement campaign, the data are interpreted to provide estimates of Boraflex degradation. Raw counts of individual panels are compared with the counts for the calibration cell with known areal density, counts from the low dose panel, and counts at the top of the cell. Analysis of this data results in a determination of the panel average areal density. This is then compared with the known as-built areal density to determine the measured panel average loss and is stated as a percentage. Comparison of the measured panel average loss is made with the corresponding designation in SLC 16.9.24 to ensure compliance and with RACKLIFE predictions to ensure validity of these predictions.

3.2 Computer Modeling (RACKLIFE)

RACKLIFE is a computer software package developed by NETCO under contract to EPRI. It is a stand-alone PC/DOS executable program that computes the loss of boron carbide from Boraflex panels in fuel storage racks.

The RACKLIFE code is based on the following principles verified through extensive laboratory testing of irradiated Boraflex specimens as discussed in Reference 6.3:

a. Boraflex is manufactured as a polydimethyl siloxane (silicon rubber) containing a powder of boron carbide, and a filler material of crystalline silica.
b. As Boraflex ages in the spent fuel pool environment, the polymer matrix is gradually broken down and converted into amorphous silica. This is a function of gamma radiation and exposure to the pool water.
c. Amorphous silica is somewhat soluble in the spent fuel pool water at increasing rates with absorbed gamma dose, pool temperature, and time. This solubilization is the physical mechanism that leads to removal of silica and boron carbide from the storage racks.
d. The amorphous silica and boron carbide from the Boraflex panels is transported into the spent fuel pool in a constant proportion. While the boron released from the spent fuel racks is indistinguishable from the boron in the boric acid added to PWR pools for criticality control (normally greater than 2000 ppm), silica concentrations in the pool are attributable almost exclusively to the Boraflex since it is the only significant source of silica. Thus, the amount of boron carbide that is lost from the Boraflex can be calculated from the silica levels, since the ratio of boron carbide to silica leaving the Boraflex is constant.
e. Boraflex degradation and the resultant silica concentration in the spent fuel pool water is a function of rack design, temperature, and operation of the pool clean-up system.

RACKLIFE performs a mass balance of $SiO_2$ in the pool and within the wrapper plate plenum that encapsulates the Boraflex panels. A simple explanation of the mass balance is that the total $SiO_2$ released by the Boraflex panels, in aggregate, is affected by the amount of $SiO_2$ in solution in the pool water and the amount removed over time by the clean-up system. The contribution of each panel to the bulk $SiO_2$ quantity is determined, based on the irradiation-time history of the panel. All other factors being equal, panels with higher gamma exposures have higher $SiO_2$ releases, and for those with equal gamma exposures, the ones that received the dose early in life have higher $SiO_2$ releases. Having calculated the $SiO_2$ released by each panel, RACKLIFE then calculates the boron carbide released, based on the fixed ratio of boron carbide to $SiO_2$.

Input parameters generally fall into the categories of pool and rack design; reactor and assembly characteristics; and pool and fuel movement history. Parameters such as the $^{10}B$ areal density, rack dimensions, number of cells and panels, reactor thermal power, assembly type, enrichment, burnup, pool water cleanup operation, silica concentration, temperature, pH, and location of fuel assemblies are all known and input based upon records maintained by the utility. The user controls the input of three main variables; source term model, clean-up system efficiency, and escape coefficients. Two source term models are available, however, the LWRDose model is selected since it typically results in higher absorbed gamma dose by the Boraflex panels. Clean-up system efficiency for the removal of silica may vary from 0% to 1% depending on the type of system that is used. It should be noted that a higher efficiency will result in a larger predicted loss of $^{10}B$ since the bulk silica concentration will be further from the saturation limit. The escape coefficient used in RACKLIFE is defined as the rate of fluid flow from the panel cavity to the bulk pool in liters/day per volume of fluid in the panel cavity in liters. It is empirically determined by comparing RACKLIFE predictions to BADGER measurements and silica concentration measurements.

The escape coefficients assumed for the McGuire Unit 1 and 2 RACKLIFE models are varied to obtain agreement with both the measured silica concentrations and BADGER results. This is performed for the purpose of benchmarking the RACKLIFE predictions to the BADGER measurements. A constant escape coefficient over time is assumed and it is assumed that the Region 1 and Region 2 escape coefficients are independent of one another. Since, in theory, the escape coefficients should be identical for Unit 1 and Unit 2 due to design similarities, it is assumed that the escape coefficients are identical for the corresponding region of each unit. The following paragraphs describe the statistical approach used to 'normalize' the RACKLIFE code to measured values determined by BADGER.

First, the Region 1 and Region 2 escape coefficients are varied until the RACKLIFE results are brought into good agreement with the BADGER results. The next step is to calculate the difference between the RACKLIFE Boraflex loss values and the BADGER Boraflex loss values. Note that these percentage values cannot be compared directly, since they are based on different as-built values. RACKLIFE assumes the same as-built density in every panel. This density is derived from the nominal Boraflex thickness which is an input to the code, and certain default values (Boraflex density, percent $B_4C$ in Boraflex, percent B in $B_4C$, and percent $^{10}B$ in B) which it applies to every panel in each of the two regions. On the other hand, BADGER bases its loss percentages on panel-specific as-built densities, which are determined from the specific certified material test reports applicable to each of the measured panels. To account for this inconsistency in the percentage loss bases, the percentage losses are converted to absolute losses in g/cm$^2$, and then the arithmetic differences are calculated.

Next, the arithmetic differences between RACKLIFE and BADGER losses (absolute losses in $g/cm^2$) are determined. A 95/95 one-sided tolerance limit for the differences is calculated in the following manner:

a) The average and standard deviation of the differences are calculated.
b) The appropriate 95/95 uncertainty is computed by the product of the standard deviation of the sample and the appropriate one-sided 95/95 K-factor for the sample size. This value is then divided by the square root of the number of panels surrounding the fuel assembly - 4 for Region 1, and 2 for Region 2. This latter operation is an appropriate reduction of the uncertainty, based on the propagation of error formula, which recognizes the greater unlikeliness of an assembly being completely surrounded by worst case panels than for having only one worst case panel.
c) The average difference and tolerance interval, which are now in terms of $g/cm^2$, are then converted back to a percentage based on the as-built values used by RACKLIFE (0.025 $g/cm^2$ for Region 1 and 0.0103 $g/cm^2$ for Region 2.)
d) Since the predictions by RACKLIFE are of Boraflex degradation, a correction factor is determined by subtracting the bias and adding the uncertainty.
e) Further iteration is performed on the escape coefficients to produce a correction factor that is slightly negative or very close to zero.

RACKLIFE predictions are performed for semi-annual intervals and used to support the designation of cell sub-region status in SLC 16.9.24. These are updated on a periodic basis when additional BADGER measurements are available to allow benchmarking to more recent data. Predictions include a margin of conservatism that is included by increasing the percentage of minimum remaining $^{10}B$ areal density by 10% when comparing RACKLIFE predictions to the limits in SLC 16.9.24. (e.g., a RACKLIFE prediction for Region 1A must show degradation less than 72.5%, not 75%.) Predictions are valid from the date of the previous prediction until the date of the prediction (e.g., a prediction on December 31, 2002 would be implemented in SLC 16.9.24 from July 1, 2002 until December 31, 2002.)

## 4.0 BADGER MEASUREMENTS

As discussed, a BADGER demonstration campaign was performed in January 1997 with 33 McGuire Unit 2 Boraflex panels evaluated (15 Region 1, 18 Region 2). Panels were selected to include those with the greatest gamma exposures. A full campaign which measured Boraflex panels in both Units 1 and 2 was performed in April 2000. A total of 30 panels in each pool were measured (15 Region 1 and 15 Region 2). Measurements in Unit 2 were performed on the same panels that were measured in January 1997. The results, excluding measurement uncertainties, are as follows:

| **Unit 1 Region 1 Boraflex, g/cm²** | | | | **BADGER Measurement** |
|---|---|---|---|---|
| | | | **As-Fab.** | **April 2000** |
| A | 4 | South | 0.0228 | 0.0231 |
| A | 7 | East | 0.0245 | 0.0172 |
| B | 2 | East | 0.0240 | 0.0157 |
| C | 1 | South | 0.0240 | 0.0173 |
| D | 12 | East | 0.0245 | 0.0201 |
| E | 13 | East | 0.0241 | 0.0188 |
| E | 13 | North | 0.0241 | 0.0171 |
| E | 13 | West | 0.0241 | 0.0235 |
| F | 13 | East | 0.0245 | 0.0271 |
| F | 13 | North | 0.0245 | 0.0201 |
| F | 13 | West | 0.0245 | 0.0200 |
| G | 13 | East | 0.0241 | 0.0187 |
| G | 13 | West | 0.0241 | 0.0270 |
| G | 14 | South | 0.0241 | 0.0322 |
| G | 15 | West | 0.0236 | 0.0239 |

| **Unit 1 Region 2 Boraflex, g/cm²** | | | | **BADGER Measurement** |
|---|---|---|---|---|
| | | | **As-Fab.** | **April 2000** |
| AA | 76 | East | 0.0094 | 0.0078 |
| AA | 78 | East | 0.0094 | 0.0076 |
| AA | 78 | South | 0.0094 | 0.0070 |
| BB | 77 | West | 0.0097 | 0.0077 |
| BB | 79 | East | 0.0091 | 0.0070 |
| BB | 79 | North | 0.0091 | 0.0076 |
| BB | 79 | West | 0.0091 | 0.0070 |
| CC | 76 | West | 0.0089 | 0.0075 |
| CC | 78 | East | 0.0092 | 0.0078 |
| CC | 78 | South | 0.0092 | 0.0071 |
| DD | 79 | East | 0.0089 | 0.0075 |
| DD | 79 | North | 0.0089 | 0.0070 |
| DD | 79 | West | 0.0089 | 0.0071 |
| KK | 4 | South | 0.0085 | 0.0082 |
| KK | 4 | West | 0.0085 | 0.0075 |

| Unit 2 Region 1 Boraflex, g/cm² | | | As-Fab. | BADGER Measurement January 1997 | April 2000 |
|---|---|---|---|---|---|
| A | 23 | South | 0.0216 | 0.0216 | 0.0168 |
| C | 13 | East | 0.0240 | 0.0200 | 0.0203 |
| C | 13 | North | 0.0240 | 0.0176 | 0.0164 |
| D | 13 | East | 0.0240 | 0.0177 | 0.0166 |
| E | 2 | West | 0.0242 | 0.0219 | 0.0168 |
| E | 13 | East | 0.0240 | 0.0187 | 0.0185 |
| E | 13 | North | 0.0240 | 0.0160 | 0.0151 |
| E | 13 | West | 0.0240 | 0.0166 | 0.0154 |
| F | 2 | East | 0.0244 | 0.0207 | 0.0221 |
| F | 12 | West | 0.0240 | 0.0192 | 0.0179 |
| F | 13 | East | 0.0240 | 0.0178 | 0.0164 |
| F | 13 | North | 0.0240 | 0.0172 | 0.0156 |
| F | 14 | East | 0.0236 | 0.0174 | 0.0166 |
| G | 12 | East | 0.0242 | 0.0182 | 0.0143 |
| H | 13 | West | 0.0236 | 0.0182 | 0.0135 |

| Unit 2 Region 2 Boraflex, g/cm² | | | As-Fab. | BADGER Measurement January 1997 | April 2000 |
|---|---|---|---|---|---|
| BB | 78 | South | 0.0078 | 0.0078 | 0.0083 |
| DD | 78 | South | 0.0082 | 0.0084 | 0.0097 |
| DD | 78 | North | 0.0082 | 0.0074 | 0.0061 |
| DD | 78 | East | 0.0082 | 0.0069 | N/A |
| FF | 78 | East | 0.0094 | 0.0090 | 0.0069 |
| FF | 78 | North | 0.0094 | 0.0080 | 0.0067 |
| HH | 78 | North | 0.0091 | 0.0080 | 0.0064 |
| HH | 78 | East | 0.0091 | 0.0093 | 0.0064 |
| KK | 3 | South | 0.0082 | 0.0082 | 0.0082 |
| KK | 78 | South | 0.0091 | 0.0089 | 0.0106 |
| KK | 78 | West | 0.0091 | 0.0081 | 0.0089 |
| KK | 78 | North | 0.0091 | 0.0091 | 0.0062 |
| MM | 78 | East | 0.0090 | 0.0090 | 0.0067 |
| MM | 78 | West | 0.0090 | 0.0076 | 0.0096 |
| MM | 78 | North | 0.0090 | 0.0087 | N/A |
| MM | 78 | South | 0.0090 | 0.0087 | 0.0117 |
| PP | 78 | South | 0.0082 | 0.0080 | N/A |
| PP | 78 | East | 0.0082 | 0.0081 | 0.0055 |

Results from the BADGER measurement campaigns shown above were compared against the then current cell designations and shown to be in compliance. Generally, the loss of boron carbide from the panels was relatively uniform. Some limited thinning may be seen on some edges or possibly along gaps and cracks, but are generally not significant.

While gap measurements are not the primary function of the BADGER measurement equipment, an assessment is made of gaps in the Boraflex panels based on the BADGER measurements performed at McGuire in April 2000. The largest gap in Region 1 is seen to be 1-2/3 inches with the largest cumulative gaps being 3 inches. In Region 2 the largest gap is seen to be 1-1/3 inches with the largest cumulative gaps being 4-2/3 inches. The gaps appeared to be somewhat randomly distributed with no preferential elevation for gap formation. Furthermore, the gap measurements indicate that the observed panel gaps are either not large enough or in concurrent locations to incur a reactivity penalty.

The next BADGER measurement campaign is being scheduled for May 2002. Panels to be measured will be selected based upon projections by RACKLIFE and will include panels that have previously been measured as well as panels which have not been measured previously. As described in Section 3, these results will be used to ensure compliance with SLC 16.9.24 and to update RACKLIFE predictions of future Boraflex conditions.

## 5.0 RACKLIFE ASSESSMENENT

A RACKLIFE model is maintained and periodically updated for the McGuire Units 1 and 2 spent fuel pool storage racks. One of the key RACKLIFE inputs is the escape coefficient assumed for the storage racks. As described in Section 3.2, the approach used for McGuire Units 1 and 2 is to vary the Region 1 and Region 2 escape coefficients to obtain the best match between the RACKLIFE results and the BADGER results for the measured panels. The escape coefficients determined based upon benchmarking to the January 1997 and April 2000 BADGER campaigns are 1.30 for Region 1 and 0.45 for Region 2.

Changes have been observed in the escape coefficients between the benchmarking of RACKLIFE to the first measurement campaign and the second measurement campaign. Previously the escape coefficients that were determined based upon benchmarking to the first BADGER measurements were 1.25 for Region 1 and 0.05 for Region 2.

Due to the complex interrelationship between the escape coefficients and their impact on the Boraflex degradation predictions, conclusions of the impact of an increase in the escape coefficient cannot be directly inferred. Other factors important to note are the bias, uncertainty, and correction factor. Inspection of these parameters shows that the increase in the escape coefficients results in a decrease in the correction factor. This is due to over-prediction of Boraflex degradation by RACKLIFE, even though the corrected results are similar for both sets of escape coefficients. Presented below are the RACKLIFE predictions on January 8, 1997 for both sets of escape coefficients and the corresponding BADGER measurements.

| **Unit 2 Region 1** | | | | **RACKLIFE Prediction** | |
|---|---|---|---|---|---|
| | | | **BADGER** | **1.25 / 0.05** | **1.30 / 0.45** |
| A | 23 | South | 0.00% | 1.97 | 1.55% |
| C | 13 | East | 16.67% | 25.43 | 27.74% |
| C | 13 | North | 26.67% | 25.59 | 27.89% |
| D | 13 | East | 26.25% | 22.52 | 26.41% |
| E | 2 | West | 9.50% | 15.53 | 19.08% |
| E | 13 | East | 22.08% | 31.93 | 33.93% |
| E | 13 | North | 33.33% | 32.30 | 33.92% |
| E | 13 | West | 30.83% | 33.85 | 35.40% |
| F | 2 | East | 15.16% | 18.32 | 22.12% |
| F | 12 | West | 20.00% | 30.36 | 32.65% |
| F | 13 | East | 25.83% | 33.86 | 35.40% |
| F | 13 | North | 28.33% | 33.36 | 35.14% |
| F | 14 | East | 26.27% | 33.84 | 35.39% |
| G | 12 | East | 24.79% | 29.45 | 31.14% |
| H | 13 | West | 22.88% | 27.02 | 27.70% |

| **Unit 2 Region 2** | | | | **RACKLIFE Prediction** | |
|---|---|---|---|---|---|
| | | | **BADGER** | **1.25 / 0.05** | **1.30 / 0.45** |
| BB | 78 | South | 0.00% | 13.83 | 21.62% |
| DD | 78 | South | -2.44% | 13.80 | 21.67% |
| DD | 78 | North | 9.76% | 13.83 | 21.75% |
| DD | 78 | East | 15.85% | 13.82 | 21.64% |
| FF | 78 | East | 4.26% | 13.82 | 21.84% |
| FF | 78 | North | 14.89% | 13.83 | 21.87% |
| HH | 78 | North | 12.09% | 13.82 | 21.72% |
| HH | 78 | East | -2.20% | 13.79 | 21.71% |
| KK | 3 | South | 0.00% | 13.83 | 3.51% |
| KK | 78 | South | 2.20% | 13.82 | 21.65% |
| KK | 78 | West | 10.99% | 13.83 | 21.73% |
| KK | 78 | North | 0.00% | 13.81 | 21.76% |
| MM | 78 | East | 0.00% | 13.82 | 21.85% |
| MM | 78 | West | 15.56% | 13.82 | 21.65% |
| MM | 78 | North | 3.33% | 13.82 | 21.88% |
| MM | 78 | South | 3.33% | 12.91 | 21.44% |
| PP | 78 | South | 2.44% | 13.83 | 21.15% |
| PP | 78 | East | 1.22% | 13.83 | 20.83% |

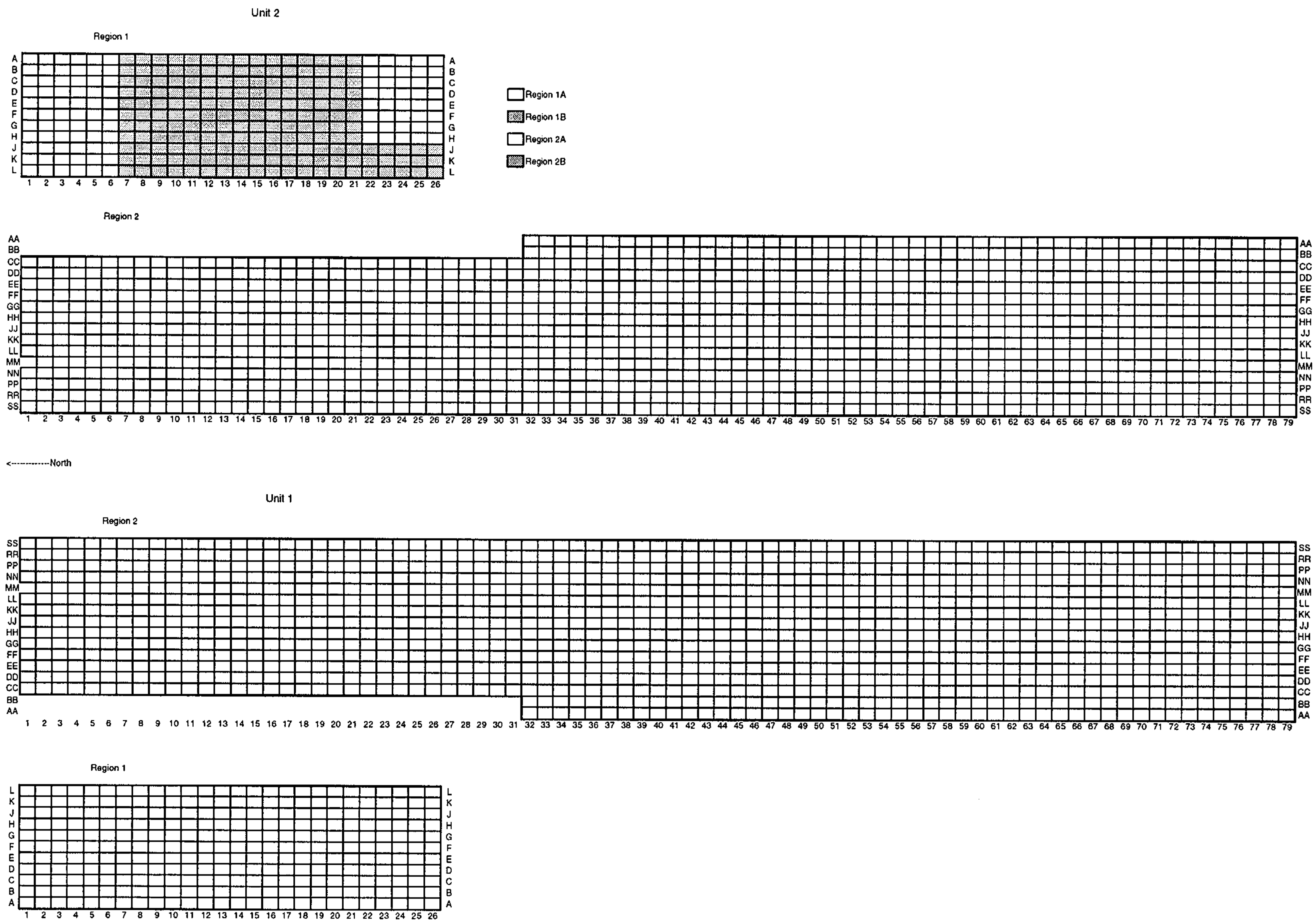
To provide flexibility in fuel storage, the criticality analysis subdivides Region 1 and Region 2, as follows:

Region 1A is assumed to have Boraflex degraded 75 % from the original design minimum (25% remaining) and Region 1B is assumed to have Boraflex degraded 100% (0% remaining).

Region 2A is assumed to have Boraflex degraded 60 % from the original design minimum (40% remaining) and Region 2B is assumed to have Boraflex degraded 100% (0% remaining).

In the Unit 1 spent fuel racks, only the Region 1A and Region 2A designations are assigned. In the Unit 2 spent fuel racks, Region 1A, Region 1B and Region 2A designations are assigned. Cell designations are presented in the following map:

**Region Designation for Individual Cells Valid Through 7/1/03**



## 6.0 LONG TERM SOLUTION

Duke Energy recognizes that long term reliance on partial credit for Boraflex is not a prudent action for maintaining the sub-critical safety margin or for effectively managing spent fuel storage. Therefore, Duke Energy has begun to search for alternatives to the reliance on partial credit for Boraflex.

Currently, Duke Energy has placed orders for dry storage systems to accelerate dry storage loading at McGuire in response to the decreasing storage capacity due to Boraflex degradation. Duke Energy has also released an RFQ to pursue a hardware solution to the spent fuel pool storage racks. Options to this solution include the replacement of the existing racks with new spent fuel storage racks which use a neutron poison material approved by the US NRC, and/or the insertion of additional neutron poison into the existing racks. Selection of the solution and the contractor to provide these services is expected early in the second quarter of 2002. Based upon projections of fuel inventory and storage capacity (in consideration of Boraflex degradation) a solution for Region 1 of Units 1 and 2 should be installed in 2003. Installation of the solution for Region 2 of Unit 1 and 2 would be completed by the end of 2005.

## 7.0 CONCLUSIONS

The initial in-situ verification for the McGuire Unit 2 spent fuel racks in January 1997 showed the Boraflex has degraded in both Region 1 and Region 2. Additional in-situ measurements performed in 2000 has shown continued degradation in Unit 2 and has confirmed degradation in Unit 1. In-situ measurements are scheduled to be performed in May 2002, in advance of the 3 year frequency commitment. These measurements will confirm the Boraflex levels assumed in the revised criticality analysis.

RACKLIFE predictions of Boraflex degradation have been in good agreement with BADGER measurements. Predictions of Boraflex degradation into the future provide the basis for the cell designations in SLC 16.9.24 and include an additional margin of 10%.

Duke Energy is also actively pursuing options to address the long term degradation of Boraflex at McGuire. These options include replacement of the storage racks, and insertion of additional neutron poison (rack or fuel assembly inserts).

## 8.0 REFERENCES

6.1 "Boraflex Degradation in Spent Fuel Pool Storage Racks," NRC Generic Letter 96-04, June 26, 1996.

6.2 Duke Power Company Letter to US NRC dated October 22, 1996, Response to Generic Letter 96-04.

6.3 Duke Energy Letter to US NRC dated December 31, 1998, Response to Generic Letter 96-04.

6.4 Duke Energy Letter to US NRC dated December 31, 1999, Response to Generic Letter 96-04.

6.5 "BADGER, a Probe for Nondestructive Testing of Residual Boron-10 Absorber Density in Spent-Fuel Storage Racks: Development and Demonstration, EPRI TR-107335, October 1997".

6.6 "BADGER Test Campaign at McGuire Unit 1," NETCO Report NET-158-01, July 31, 2000.

6.7 "BADGER Test Campaign at McGuire Unit 2," NETCO Report NET-158-02, July 18, 2000.

6.3 "The RACKLIFE Boraflex Rack Life Extension Computer Code: Theory and Numerics", DRAFT, NETCO, May 1997.

# ATTACHMENT 8

# MCGUIRE NUCLEAR STATION
# PROPOSED REVISION TO UFSAR
# CHAPTER 16, "SELECTED LICENSEE COMMITMENTS"

## 16.9 AUXILIARY SYSTEMS

### 16.9.24 Spent Fuel Pool Storage Rack Poison Material

COMMITMENT

a. The Region 1 panel average storage rack poison material Boron 10 areal density shall be greater than or equal to:

$0.005$ gm $B_{10}/cm^2$ for Region 1A
$0$ gm $B_{10}/cm^2$ for Region 1B

b. The Region 2 panel average storage rack poison material Boron 10 areal density shall be greater than or equal to:

~~0.003~~ 0.0024 gm $B_{10}/cm^2$ for Region 2A
$0$ gm $B_{10}/cm^2$ for Region 2B

APPLICABILITY When a fuel assembly is stored in a spent fuel rack cell location.

REMEDIAL ACTIONS

| CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. Panel average storage rack poison material Boron 10 areal density not within limits. | A.1 Perform ITS SR 3.7.14.1 | 1 hour<br>**AND**<br>Every 24 hours thereafter until the affected fuel assembly is moved. |
| | **AND** | |
| | A.2.1 Verify that the fuel assembly in the affected location meets the requirements of ITS LCO 3.7.15(b) for Region 1.<br>OR | 1 hour |

| (continued) CONDITION | REQUIRED ACTION | COMPLETION TIME |
|---|---|---|
| A. (continued). | A.2.2 Verify that the fuel assembly in the affected location meets the requirements of ITS LCO 3.7.15(d) for Region 2. | 1 hour |
| | <u>OR</u> | |
| | A.2.3 Initiate actions to move the affected fuel assembly to an acceptable location. | Immediately |

TESTING REQUIREMENTS

| TEST | | FREQUENCY |
|---|---|---|
| TR 16.9.24.1 | Verify that the panel average spent fuel pool storage rack poison material is within limits. | 3 years |

BASES

The McGuire spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum.

It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel (>$10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. The potential degradation mechanisms with respect to boraflex in spent fuel storage racks include:

(1) gamma radiation-induced shrinkage of boraflex and the potential for developing tears or gaps in the material, and

(2) gradual long-term boraflex degradation over the intended service life of the racks as a result of gamma irradiation and exposure to the spent fuel pool environment.

Thus, the B4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks". To address this degradation, the spent fuel racks have been analyzed taking credit for soluble boron as allowed in WCAP-14416-NP-A, "Westinghouse Spent Fuel Rack Criticality Analysis Methodology," Revision 1, November 1996. This methodology ensures that the spent fuel rack multiplication factor, $k_{eff}$ is less than or equal to 0.95. Codes, methods and techniques used in the McGuire criticality analysis are used to satisfy this $k_{eff}$ criterion. The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum of 4.75 weight percent Uranium-235 while maintaining $k_{eff} \leq 0.95$ including uncertainties, tolerances, bias, and credit for soluble boron. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff}$ is maintained less than or equal to 0.95. The soluble boron concentration required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions is ~~730~~ 850 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis without the presence of the soluble boron in the pool. Credit is taken for reactivity depletion due to fuel burnup and reduced credit for the Boraflex neutron absorber panels.

The limits specified for the panel average storage rack poison material Boron 10 areal density ensures the $k_{eff}$ of the spent fuel pool will always remain < 1.00, assuming the pool to be flooded with unborated water. The specified limit of Boron 10 areal density in boraflex preserves the assumptions used in the analyses of the potential criticality accident scenarios. These limits are the minimum required concentration for fuel assembly storage. The criticality analysis performed shows that the acceptance criteria for criticality is met for the storage of fuel assemblies with soluble boron credit, reduced credit for the Boraflex panels and the storage configurations and enrichment limits Specified by ITS LCO 3.7.15. The storage configuration requirements specified by ITS LCO 3.7.15 establish four regions within the spent fuel pool storage racks. Figure 16.9.24-1 illustrates the four regions for the Unit 1 spent fuel pool and Figure 16.9.24-2 illustrates the four regions for the Unit 2 pool. The limits specified are not applicable if a storage cell location does not contain a fuel assembly.

The REQUIRED ACTIONS associated with this Selected Licensee Commitment (SLC) are designed to ensure that an unplanned criticality event cannot occur as a result of degraded boraflex conditions. REQUIRED ACTION A.1 verifies the Spent Fuel Pool boron concentration to be within Technical Specification 3.7.14 limits. These limits are based on the cycle-specific Core Operating Limits Requirements (COLR) document. The COLR Spent Fuel Pool boron concentration cannot be less than 2675 ppm soluble boron for any specific cycle (note that the initial boron concentration used in the Spent Fuel Pool boron dilution analysis is 2475 ppm soluble boron). If ITS SR 3.7.14.1 indicates boron concentrations less than the acceptable level, the associated REQUIRED ACTIONS are to immediately suspend movement of fuel assemblies in the pool area and to immediately initiate boron additions to raise the boron concentration to acceptable levels. REQUIRED ACTIONS A.2.1 and A.2.2 associated with this SLC determine if the assembly can be qualified for storage in Region 1B or Region 2B. If the assembly cannot be stored in one of these regions, REQUIRED ACTION A.2.3 requires that actions be initiated immediately to move the affected fuel assembly to an acceptable location.

There may be circumstances that will prevent the movement of the affected assembly in a reasonable time period. For example, if the pool is nearly full, there may not be enough spaces available to meet the required storage configurations of ITS LCO 3.7.15. In this case, it is acceptable to continue REQUIRED ACTION A.1 until the affected fuel assembly can be moved to an acceptable location. The
daily verification of boron concentration per ITS SR 3.7.14.1 ensures the assumptions used in the associated criticality analyses are maintained. There is a large amount of margin between the COLR boron concentration and the boron concentration needed to maintain subcritical conditions in the Spent Fuel Pool. Daily verifications are considered to be adequate to ensure that no dilution evolution could go undetected for an extended period resulting in boron concentrations less than the minimum amounts necessary for maintaining subcritical conditions.

The testing requirements will verify that the Boron 10 areal density is within acceptable limits. The preferred method for verifying the Boron 10 areal density would be in-situ testing at least every three years. Testing may be performed more frequently based on engineering judgment, spent fuel pool water chemistry, and modeling projections of boraflex degradation.

## FIGURE 16.9.24-1
## UNIT 1 SPENT FUEL POOL SUB-REGION MAP
## Region Designation for Individual Cells Valid Through 7/1/03

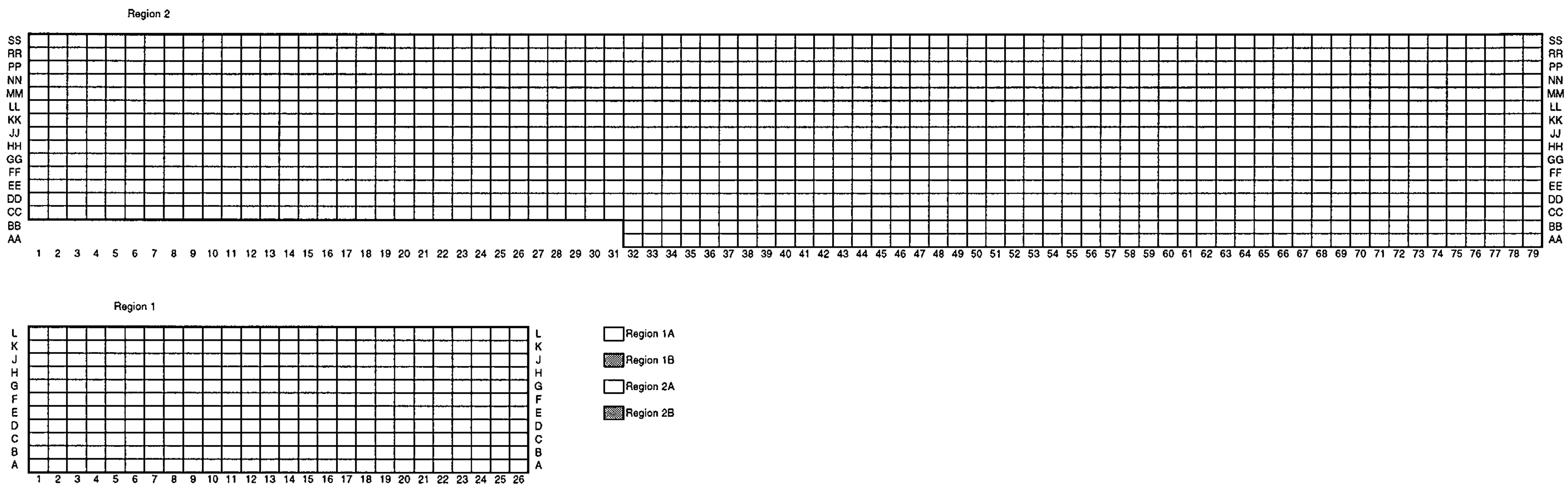
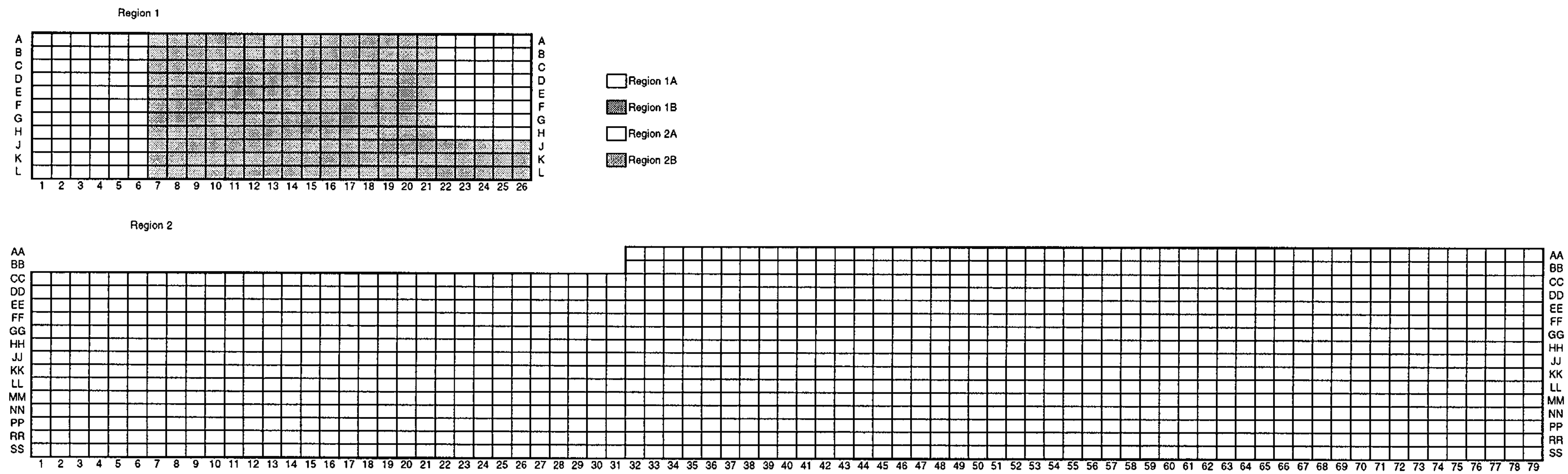


FIGURE 16.9.24-2
UNIT 2 SPENT FUEL POOL SUB-REGION MAP
Region Designation for Individual Cells Valid Through 7/1/03



**REFERENCES:**

1. UFSAR, Section 9.1.2.
2. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. M89744 and M89745), November 6, 1995.
3. 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).
4. UFSAR, Section 15.7.4.
5. 10 CFR 50.36, Technical Specifications, (c)(2)(ii).
6. NRC Generic Letter 96-04: Boraflex Degradation in Spent Fuel Pool Storage Racks, June 26, 1996.
7. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.
8. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. MA9730 and MA9731), November 27, 2000.

# ATTACHMENT 9

# MCGUIRE NUCLEAR STATION
# PROPOSED REVISIONS TO TECHNICAL SPECIFICATION BASES

# B 3.7 PLANT SYSTEMS

## B 3.7.14 Spent Fuel Pool Boron Concentration

BASES

BACKGROUND

In the two region poison fuel storage rack (Refs. 1 and 2) design, the spent fuel pool is divided into two separate and distinct regions. Region 1, with 286 storage positions, is designed and generally reserved for temporary storage of new or partially irradiated fuel. Region 2, with 1177 storage positions, is designed and generally used for normal, long term storage of permanently discharged fuel that has achieved qualifying burnup levels.

The McGuire spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, each region of the spent fuel pool has been divided into two sub-regions; with and without credit for Boraflex. For the regions taking credit for Boraflex, a minimum amount of Boraflex was assumed that is less than the original design minimum $B_{10}$ areal density.

The McGuire spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 3. The methodology ensures that the spent fuel rack multiplication factor, $k_{eff}$, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 4) and NRC guidance (Ref. 5). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 4.75 weight percent Uranium-235 while maintaining $k_{eff} \leq$

BASES

BACKGROUND (continued)

0.95 including uncertainties, tolerances, bias, and credit for soluble boron. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff}$ is maintained less than or equal to 0.95. The soluble boron concentration required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions is ~~730~~850 ppm. In addition, sub-criticality of the pool ($k_{eff}$ < 1.0) is assured on a 95/95 basis, without the presence of the soluble boron in the pool. The criticality analysis performed shows that the acceptance criteria for criticality is met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, the presence of Integral Fuel Burnable Absorber (IFBA) rods, reduced credit for the Boraflex neutron absorber panels and storage configurations and enrichment limits Specified by LCO 3.7.15.

APPLICABLE SAFETY ANALYSES

Most accident conditions do not result in an increase in reactivity of the racks in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, three accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a significant change in the spent fuel pool water temperature (either the loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature or a large makeup to the pool with cold water which causes a decrease in the pool water temperature) and the third is the misloading of a fuel assembly into a location which the restrictions on location, enrichment, burnup and number of IFBA rods is not satisfied.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 6) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the ~~730~~850 ppm required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by either of

BASES

APPLICABLE SAFETY ANALYSES (continued)

these postulated accidents and to maintain $k_{eff}$ less than or equal to 0.95. It was found that a spent fuel pool boron concentration of 1470 ppm was adequate to mitigate these postulated criticality related accidents and to maintain $k_{eff}$ less than or equal to 0.95. Specification 3.7.14 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Specification 4.3.1.1 c. requires that the spent fuel rack ~~$k_{eff}$ be~~ less than or equal to 0.95 when flooded with water borated to ~~730~~850 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 $k_{eff}$ design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to ~~730~~850 ppm is not a credible event.

The concentration of dissolved boron in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 5).

LCO

The spent fuel pool boron concentration is required to be within the limits specified in the COLR. The specified concentration of dissolved boron in the spent fuel pool preserves the assumptions used in the analyses of the potential criticality accident scenarios as described in Reference 4. This concentration of dissolved boron is the minimum required concentration for fuel assembly storage and movement within the spent fuel pool.

APPLICABILITY

This LCO applies whenever fuel assemblies are stored in the spent fuel pool.

ACTIONS

A.1 and A.2

The Required Actions are modified by a Note indicating that LCO 3.0.3 does not apply.

When the concentration of boron in the fuel storage pool is less than required, immediate 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. The concentration of boron is restored simultaneously with suspending movement of fuel assemblies.

BASES

ACTIONS (continued)

If the LCO is not met while moving irradiated fuel assemblies in MODE 5 or 6, LCO 3.0.3 would not be applicable. If moving irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the fuel movement is independent of reactor operation. Therefore, inability to suspend movement of fuel assemblies is not sufficient reason to require a reactor shutdown.

SURVEILLANCE REQUIREMENTS

SR 3.7.14.1

This SR verifies that the concentration of boron in the spent fuel pool is within the required limit. As long as this SR is met, the analyzed accidents are fully addressed. The 7 day Frequency is appropriate because no major replenishment of pool water is expected to take place over such a short period of time.

REFERENCES

1. UFSAR, Section 9.1.2.
2. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. MA9730 and MA9731), November 27, 2000.~~Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. M89744 and M89745), November 6, 1995.~~
3. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.
4. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.
5. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.
6. 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).
7. 10 CFR 50.36, Technical Specifications, (c)(2)(ii).
8. UFSAR, Section 15.7.4.

## B 3.7 PLANT SYSTEMS

## B 3.7.15 Spent Fuel Assembly Storage

BASES

BACKGROUND

In the two region poison fuel storage rack (Refs. 1 and 2) design, the spent fuel pool is divided into two separate and distinct regions. Region 1, with 286 storage positions, is designed and generally reserved for temporary storage of new or partially irradiated fuel. Region 2, with 1177 storage positions, is designed and generally used for normal, long term storage of permanently discharged fuel that has achieved qualifying burnup levels.

The McGuire spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, each region of the spent fuel pool has been divided into two sub-regions; with and without credit for Boraflex. For the regions taking credit for Boraflex, a minimum amount of Boraflex was assumed that is less than the original design minimum B10 areal density.

Two storage configurations are defined for each region; Unrestricted and Restricted storage. Unrestricted storage allows storage in all cells without restriction on the storage configuration. Restricted storage allows storage of higher reactivity fuel when restricted to a certain storage

BASES

BACKGROUND (continued)

configuration with lower reactivity fuel. A third loading pattern, Checkerboard storage, was defined for Regions 1B, 2A and 2B. Checkerboard storage allows storage of the highest reactivity fuel in each region when checkerboarded with empty storage cells.

The McGuire spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 3. The methodology ensures that the spent fuel rack multiplication factor, $k_{eff}$, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 4) and NRC guidance (Ref. 5). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 4.75 weight percent Uranium-235 while maintaining $k_{eff} \leq$ 0.95 including uncertainties, tolerances, bias, and credit for soluble boron. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff}$ is maintained less than or equal to 0.95. The soluble boron concentration required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions is ~~730~~850 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis, without the presence of the soluble boron in the pool. The criticality analysis performed shows that the acceptance criteria for criticality is met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, the presence of Integral Fuel Burnable Absorber (IFBA) rods, reduced credit for the Boraflex neutron absorber panels and storage configurations and enrichment limits Specified by LCO 3.7.15.

APPLICABLE SAFETY ANALYSES

Most accident conditions do not result in an increase in reactivity of the racks in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, three accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a significant change in the spent fuel pool water temperature (either the loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature or a large makeup to the pool with cold water which causes a decrease in the pool water temperature) and the third is the misloading of a fuel assembly into a location which the restrictions on location, enrichment, burnup and number of IFBA rods is not satisfied.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter

BASES

APPLICABLE SAFETY ANALYSES (continued)

(Ref. 6) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the ~~730~~850 ppm required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by either of these postulated accidents and to maintain $k_{eff}$ less than or equal to 0.95. It was found that a spent fuel pool boron concentration of 1470 ppm was adequate to mitigate these postulated criticality related accidents and to maintain $k_{eff}$ less than or equal to 0.95. Specification 3.7.14 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Specification 4.3.1.1 c. requires that the spent fuel rack $k_{eff}$ be less than or equal to 0.95 when flooded with water borated to ~~730~~850 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 $k_{eff}$ design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to ~~730~~850 ppm is not a credible event.

The configuration of fuel assemblies in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 7).

LCO

a

The restrictions on the placement of fuel assemblies within the Region 1A of the spent fuel pool, which have a number of IFBA rods greater than or equal to the minimum qualifying number of IFBA rods in Table 3.7.15-1 or accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-2 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to ~~730~~850 ppm. Fuel assemblies not meeting the criteria of Tables 3.7.15-1 or 3.7.15-2 shall be stored in accordance with Figure 3.7.15-1.

LCO (continued)

b

The restrictions on the placement of fuel assemblies within the Region 1B of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-4 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to ~~730~~850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-4 shall be stored in accordance with either Figure 3.7.15-2 and Table 3.7.15-5 for Restricted storage, or Figure 3.7.15-3 for Checkerboard storage.

c

The restrictions on the placement of fuel assemblies within the Region 2A of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-7 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to ~~730~~850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-7 shall be stored in accordance with either Figure 3.7.15-4 and Table 3.7.15-8 for Restricted storage, or Figure 3.7.15-5 for Checkerboard storage.

d

The restrictions on the placement of fuel assemblies within the Region 2B of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-10 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to ~~730~~850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-10 shall be stored in accordance with either Figure 3.7.15-6 and Table 3.7.15-11 for Restricted storage, or Figure 3.7.15-7 for Checkerboard storage.

APPLICABILITY

This LCO applies whenever any fuel assembly is stored in the spent fuel pool.

ACTIONS

A.1

Required Action A.1 is modified by a Note indicating that LCO 3.0.3 does not apply.

When the configuration of fuel assemblies stored in the spent fuel pool is not in accordance with the LCO, the immediate action is to initiate action

LCO (continued)

to make the necessary fuel assembly movement(s) to bring the configuration into compliance.

If unable to move irradiated fuel assemblies while in MODE 5 or 6, LCO 3.0.3 would not be applicable. If unable to move irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the action is independent of reactor operation. Therefore, inability to move fuel assemblies is not sufficient reason to require a reactor shutdown.

SURVEILLANCE REQUIREMENTS

SR 3.7.15.1

This SR verifies by administrative means that the fuel assembly is in accordance with the configurations specified in the accompanying LCO.

REFERENCES

1. UFSAR, Section 9.1.2.

2. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. MA9730 and MA9731), November 27, 2000.~~Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. M89744 and M89745), November 6, 1995.~~

3. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.

4. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.

5. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.

6. 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).

7. 10 CFR 50.36, Technical Specifications, (c)(2)(ii).

# ATTACHMENT 10

# REVISED MCGUIRE NUCLEAR STATION TECHNICAL SPECIFICATION BASES

B 3.7 PLANT SYSTEMS

B 3.7.14 Spent Fuel Pool Boron Concentration

## BASES

BACKGROUND

In the two region poison fuel storage rack (Refs. 1 and 2) design, the spent fuel pool is divided into two separate and distinct regions. Region 1, with 286 storage positions, is designed and generally reserved for temporary storage of new or partially irradiated fuel. Region 2, with 1177 storage positions, is designed and generally used for normal, long term storage of permanently discharged fuel that has achieved qualifying burnup levels.

The McGuire spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, each region of the spent fuel pool has been divided into two sub-regions; with and without credit for Boraflex. For the regions taking credit for Boraflex, a minimum amount of Boraflex was assumed that is less than the original design minimum $B_{10}$ areal density.

The McGuire spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 3. The methodology ensures that the spent fuel rack multiplication factor, $k_{eff}$, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 4) and NRC guidance (Ref. 5). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 4.75 weight percent Uranium-235 while maintaining $k_{eff} \leq$

BASES

BACKGROUND (continued)

0.95 including uncertainties, tolerances, bias, and credit for soluble boron. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff}$ is maintained less than or equal to 0.95. The soluble boron concentration required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions is 850 ppm. In addition, sub-criticality of the pool ($k_{eff} < 1.0$) is assured on a 95/95 basis, without the presence of the soluble boron in the pool. The criticality analysis performed shows that the acceptance criteria for criticality is met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, the presence of Integral Fuel Burnable Absorber (IFBA) rods, reduced credit for the Boraflex neutron absorber panels and storage configurations and enrichment limits Specified by LCO 3.7.15.

APPLICABLE SAFETY ANALYSES

Most accident conditions do not result in an increase in reactivity of the racks in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, three accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a significant change in the spent fuel pool water temperature (either the loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature or a large makeup to the pool with cold water which causes a decrease in the pool water temperature) and the third is the misloading of a fuel assembly into a location which the restrictions on location, enrichment, burnup and number of IFBA rods is not satisfied.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter (Ref. 6) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 850 ppm required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by either of

BASES

APPLICABLE SAFETY ANALYSES (continued)

these postulated accidents and to maintain $k_{eff}$ less than or equal to 0.95. It was found that a spent fuel pool boron concentration of 1470 ppm was adequate to mitigate these postulated criticality related accidents and to maintain $k_{eff}$ less than or equal to 0.95. Specification 3.7.14 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Specification 4.3.1.1 c. requires that the spent fuel rack $k_{eff}$ be less than or equal to 0.95 when flooded with water borated to 850 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 $k_{eff}$ design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to 850 ppm is not a credible event.

The concentration of dissolved boron in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 5).

LCO

The spent fuel pool boron concentration is required to be within the limits specified in the COLR. The specified concentration of dissolved boron in the spent fuel pool preserves the assumptions used in the analyses of the potential criticality accident scenarios as described in Reference 4. This concentration of dissolved boron is the minimum required concentration for fuel assembly storage and movement within the spent fuel pool.

APPLICABILITY

This LCO applies whenever fuel assemblies are stored in the spent fuel pool.

ACTIONS

A.1 and A.2

The Required Actions are modified by a Note indicating that LCO 3.0.3 does not apply.

When the concentration of boron in the fuel storage pool is less than required, immediate 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. The concentration of boron is restored simultaneously with suspending movement of fuel assemblies.

BASES

ACTIONS (continued)

If the LCO is not met while moving irradiated fuel assemblies in MODE 5 or 6, LCO 3.0.3 would not be applicable. If moving irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the fuel movement is independent of reactor operation. Therefore, inability to suspend movement of fuel assemblies is not sufficient reason to require a reactor shutdown.

SURVEILLANCE REQUIREMENTS

SR 3.7.14.1

This SR verifies that the concentration of boron in the spent fuel pool is within the required limit. As long as this SR is met, the analyzed accidents are fully addressed. The 7 day Frequency is appropriate because no major replenishment of pool water is expected to take place over such a short period of time.

REFERENCES

1. UFSAR, Section 9.1.2.

2. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. MA9730 and MA9731), November 27, 2000.

3. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.

4. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.

5. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.

6. 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).

7. 10 CFR 50.36, Technical Specifications, (c)(2)(ii).

8. UFSAR, Section 15.7.4.

## B 3.7 PLANT SYSTEMS

## B 3.7.15 Spent Fuel Assembly Storage

BASES

BACKGROUND

In the two region poison fuel storage rack (Refs. 1 and 2) design, the spent fuel pool is divided into two separate and distinct regions. Region 1, with 286 storage positions, is designed and generally reserved for temporary storage of new or partially irradiated fuel. Region 2, with 1177 storage positions, is designed and generally used for normal, long term storage of permanently discharged fuel that has achieved qualifying burnup levels.

The McGuire spent fuel storage racks contain Boraflex neutron-absorbing panels that surround each storage cell on all four sides (except for peripheral sides). The function of these Boraflex panels is to ensure that the reactivity of the stored fuel assemblies is maintained within required limits. Boraflex, as manufactured, is a silicon rubber material that retains a powder of boron carbide (B4C) neutron absorbing material. The Boraflex panels are enclosed in a formed stainless steel wrapper sheet that is spot-welded to the storage tube. The wrapper sheet is bent at each end to complete the enclosure of the Boraflex panel. The Boraflex panel is contained in the plenum area between the storage tube and the wrapper plate. Since the wrapper plate enclosure is not sealed, spent fuel pool water is free to circulate through the plenum. It has been observed that after Boraflex receives a high gamma dose from the stored irradiated fuel ($>10^{10}$ rads) it can begin to degrade and dissolve in the wet environment. Thus, the B4C poison material can be removed, thereby reducing the poison worth of the Boraflex sheets. This phenomenon is documented in NRC Generic Letter 96-04, "Boraflex Degradation in Spent Fuel Pool Storage Racks".

To address this degradation, each region of the spent fuel pool has been divided into two sub-regions; with and without credit for Boraflex. For the regions taking credit for Boraflex, a minimum amount of Boraflex was assumed that is less than the original design minimum B10 areal density.

Two storage configurations are defined for each region; Unrestricted and Restricted storage. Unrestricted storage allows storage in all cells without restriction on the storage configuration. Restricted storage allows storage of higher reactivity fuel when restricted to a certain storage

BASES

BACKGROUND (continued)

configuration with lower reactivity fuel. A third loading pattern, Checkerboard storage, was defined for Regions 1B, 2A and 2B. Checkerboard storage allows storage of the highest reactivity fuel in each region when checkerboarded with empty storage cells.

The McGuire spent fuel storage racks have been analyzed taking credit for soluble boron as allowed in Reference 3. The methodology ensures that the spent fuel rack multiplication factor, $k_{eff}$, is less than or equal to 0.95 as recommended in ANSI/ANS-57.2-1983 (Ref. 4) and NRC guidance (Ref. 5). The spent fuel storage racks are analyzed to allow storage of fuel assemblies with enrichments up to a maximum nominal enrichment of 4.75 weight percent Uranium-235 while maintaining $k_{eff} \leq$ 0.95 including uncertainties, tolerances, bias, and credit for soluble boron. Soluble boron credit is used to offset uncertainties, tolerances, and off-normal conditions and to provide subcritical margin such that the spent fuel pool $k_{eff}$ is maintained less than or equal to 0.95. The soluble boron concentration required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions is 850 ppm. In addition, sub-criticality of the pool ($k_{eff}$ < 1.0) is assured on a 95/95 basis, without the presence of the soluble boron in the pool. The criticality analysis performed shows that the acceptance criteria for criticality is met for the storage of fuel assemblies when credit is taken for reactivity depletion due to fuel burnup, the presence of Integral Fuel Burnable Absorber (IFBA) rods, reduced credit for the Boraflex neutron absorber panels and storage configurations and enrichment limits Specified by LCO 3.7.15.

APPLICABLE SAFETY ANALYSES

Most accident conditions do not result in an increase in reactivity of the racks in the spent fuel pool. Examples of these accident conditions are the drop of a fuel assembly on top of a rack, the drop of a fuel assembly between rack modules (rack design precludes this condition), and the drop of a fuel assembly between rack modules and the pool wall. However, three accidents can be postulated which could result in an increase in reactivity in the spent fuel storage pools. The first is a drop or placement of a fuel assembly into the cask loading area. The second is a significant change in the spent fuel pool water temperature (either the loss of normal cooling to the spent fuel pool water which causes an increase in the pool water temperature or a large makeup to the pool with cold water which causes a decrease in the pool water temperature) and the third is the misloading of a fuel assembly into a location which the restrictions on location, enrichment, burnup and number of IFBA rods is not satisfied.

For an occurrence of these postulated accidents, the double contingency principle discussed in ANSI N-16.1-1975 and the April 1978 NRC letter

BASES

APPLICABLE SAFETY ANALYSES (continued)

(Ref. 6) can be applied. This states that one is not required to assume two unlikely, independent, concurrent events to ensure protection against a criticality accident. Thus, for these postulated accident conditions, the presence of additional soluble boron in the spent fuel pool water (above the 850 ppm required to maintain $k_{eff}$ less than or equal to 0.95 under normal conditions) can be assumed as a realistic initial condition since not assuming its presence would be a second unlikely event.

Calculations were performed to determine the amount of soluble boron required to offset the highest reactivity increase caused by either of these postulated accidents and to maintain $k_{eff}$ less than or equal to 0.95. It was found that a spent fuel pool boron concentration of 1470 ppm was adequate to mitigate these postulated criticality related accidents and to maintain $k_{eff}$ less than or equal to 0.95. Specification 3.7.14 ensures the spent fuel pool contains adequate dissolved boron to compensate for the increased reactivity caused by these postulated accidents.

Specification 4.3.1.1 c. requires that the spent fuel rack $k_{eff}$ be less than or equal to 0.95 when flooded with water borated to 850 ppm. A spent fuel pool boron dilution analysis was performed which confirmed that sufficient time is available to detect and mitigate a dilution of the spent fuel pool before the 0.95 $k_{eff}$ design basis is exceeded. The spent fuel pool boron dilution analysis concluded that an unplanned or inadvertent event which could result in the dilution of the spent fuel pool boron concentration to 850 ppm is not a credible event.

The configuration of fuel assemblies in the spent fuel pool satisfies Criterion 2 of 10 CFR 50.36 (Ref. 7).

LCO

a

The restrictions on the placement of fuel assemblies within the Region 1A of the spent fuel pool, which have a number of IFBA rods greater than or equal to the minimum qualifying number of IFBA rods in Table 3.7.15-1 or accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-2 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to 850 ppm. Fuel assemblies not meeting the criteria of Tables 3.7.15-1 or 3.7.15-2 shall be stored in accordance with Figure 3.7.15-1.

BASES

LCO (continued)

b

The restrictions on the placement of fuel assemblies within the Region 1B of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-4 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to 850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-4 shall be stored in accordance with either Figure 3.7.15-2 and Table 3.7.15-5 for Restricted storage, or Figure 3.7.15-3 for Checkerboard storage.

c

The restrictions on the placement of fuel assemblies within the Region 2A of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-7 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to 850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-7 shall be stored in accordance with either Figure 3.7.15-4 and Table 3.7.15-8 for Restricted storage, or Figure 3.7.15-5 for Checkerboard storage.

d

The restrictions on the placement of fuel assemblies within the Region 2B of the spent fuel pool, which have accumulated burnup greater than or equal to the minimum qualified burnups in Table 3.7.15-10 in the accompanying LCO, ensures the $k_{eff}$ of the spent fuel pool will always remain $\leq$ 0.95, assuming the pool to be flooded with water borated to 850 ppm. Fuel assemblies not meeting the criteria of Table 3.7.15-10 shall be stored in accordance with either Figure 3.7.15-6 and Table 3.7.15-11 for Restricted storage, or Figure 3.7.15-7 for Checkerboard storage.

APPLICABILITY

This LCO applies whenever any fuel assembly is stored in the spent fuel pool.

ACTIONS

A.1

Required Action A.1 is modified by a Note indicating that LCO 3.0.3 does not apply.

When the configuration of fuel assemblies stored in the spent fuel pool is not in accordance with the LCO, the immediate action is to initiate action

BASES

LCO (continued)

to make the necessary fuel assembly movement(s) to bring the configuration into compliance.

If unable to move irradiated fuel assemblies while in MODE 5 or 6, LCO 3.0.3 would not be applicable. If unable to move irradiated fuel assemblies while in MODE 1, 2, 3, or 4, the action is independent of reactor operation. Therefore, inability to move fuel assemblies is not sufficient reason to require a reactor shutdown.

SURVEILLANCE REQUIREMENTS

SR 3.7.15.1

This SR verifies by administrative means that the fuel assembly is in accordance with the configurations specified in the accompanying LCO.

REFERENCES

1. UFSAR, Section 9.1.2.

2. Issuance of Amendments, McGuire Nuclear Station, Units 1 and 2 (TAC NOS. MA9730 and MA9731), November 27, 2000.

3. WCAP-14416-NP-A, Westinghouse Spent Fuel Rack Criticality Analysis Methodology, Revision 1, November 1996.

4. American Nuclear Society, "American National Standard Design Requirements for Light Water Reactor Fuel Storage Facilities at Nuclear Power Plants," ANSI/ANS-57.2-1983, October 7, 1983.

5. Nuclear Regulatory Commission, Memorandum to Timothy Collins from Laurence Kopp, "Guidance on the Regulatory Requirements for Criticality Analysis of Fuel Storage at Light Water Reactor Power Plants," August 19, 1998.

6. 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).

7. 10 CFR 50.36, Technical Specifications, (c)(2)(ii).