- The channel is present and attached to the fuel assembly in the standard fashion; and
- The channel is essentially undamaged; and
- The maximum planar average enrichment of the assembly is less than or equal to 3.3 wt% $^{235}$U

This analysis covers older assemblies, where the cladding integrity is uncertain, and where a verification of the cladding condition is prohibitive. An example of this type of fuel is the so-called CILC fuel, which has potential corrosion-induced damaged to the cladding but does not have grossly breached spent fuel rods.

The presence of the essentially undamaged and attached channel confines the fuel rods to a limited volume and the low enrichment, required for all assemblies in the MPC, limits the reactivity of the fuel even under optimum moderation conditions. Due to the uncertain cladding condition, the analysis of this fuel follows essentially the same approach as that for the Damaged Fuel and Fuel Debris, i.e. bare fuel rod arrays of varying sizes are analyzed within the confines of the channel. This is an extremely conservative modeling approach for this condition, since reconfiguration is not expected and cladding would still be present. The results of this conservative analysis are listed in Table 6.4.8 and show that the system remains below the regulatory limit with these assemblies in all cells of the MPC-89, without DFCs.

These results confirm that even with unknown cladding condition the maximum $k_{eff}$ values are below the regulatory limit when fully flooded and loaded with any of the BWR candidate fuel assemblies, therefore if the cladding is not grossly breached and the fuel assembly structurally sound it can be considered undamaged when loading in an MPC-89.

## 6.4.10 BWR Fuel with a Partial Gadolinium Credit

### 6.4.10.1 Introduction

Initial calculations to qualify BWR fuel for the MPC-89 were performed assuming fresh (unburned) fuel in the assembly, and neglecting any burnable absorber that may be present in the assembly. In order to ensure that the reactivities are below the acceptable limit specified in Section 6.1, this approach results in upper enrichment limits for the assemblies. These limits are included in the specification of the allowable contents in Section 2.1. Depending on the assembly class, those limits can be as low as 4.5 wt% $^{235}$U. For more modern BWR assembly, such as the 10x10 assemblies characterized through assembly class 10x10A through 10x10G, actual enrichments that are used for those assemblies are by now up to 4.9 wt% $^{235}$U, hence they exceed those limits. In order to increase the upper enrichment limit for those 10x10 assemblies, and qualify them for storage in the MPC-89, i.e. ensure that the maximum reactivity for those higher enriched assemblies is below the limit of 0.95, an additional set of design basis calculations is presented in this subsection where some of the burnable neutron absorbers present in those assemblies are credited. Based on this approach, an upper enrichment limit of 5 wt% $^{235}$U is

qualified for selected assembly types. The additional requirements with respect to the credit neutron absorber are clearly defined, and added to the specification of the allowable content in Subsection 2.1.7. [

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In summary, the approach is termed "Partial Gadolinium Credit" since only Gadolinium is credited, and only a part of the amount present in modern BWR assemblies is credited, both in terms of the number of rods containing Gadolinium, and the amount of Gadolinium contained any single rod, and just enough to ensure maximum reactivity is below 0.95 under all conditions. All design basis calculations are still performed assuming fresh unirradiated fuel, i.e. no credit for fuel burnup is applied in this approach.

The following Paragraph 6.4.10.2 describes details of the methodology, Paragraph 6.4.10.3 describes the design basis calculations, and Paragraph 6.4.10.4 presents various studies to show that the selected parameters are conservative.

6.4.10.2 Methodology

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### 6.4.10.3 Design Basis Calculations

Partial Gadolinium Credit is only applied to assembly classes 10x10A through 10x10G. The results of the corresponding design basis calculations are summarized in Table 6.4.14. For comparison, the table also shows the results of the design basis calculations with the lower enrichment limits and no Gadolinium credit from Section 6.1. It also shows, for information only, results of calculations with 5 wt% $^{235}$U enriched fuel without Gadolinium Credit.
For all cases with 5 wt% $^{235}$U enrichment and Partial Gadolinium Credit, the maximum $k_{eff}$ is below the limits specified in Section 6.1.

### 6.4.10.4 Studies

There are two assumptions in the methodology outlined in Paragraph 6.4.10.2 that are supported in this paragraph through studies, in order to verify that the assumptions result in a conservative methodology. These are the selected location of the Gadolinium Rod(s), and the assumption of fresh fuel in the calculations.

#### 6.4.10.4.1 Gadolinium Rod Locations

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### 6.4.10.4.2 Fresh Fuel Assumption

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TABLE 6.4.13

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## TABLE 6.4.14

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Figure 6.4.3: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure 6.4.4: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure 6.4.5: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure 6.4.6: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

Figure 6.4.7: PROPRIETARY INFORMATION WITHHELD PER 10CFR2.390

## 6.7 REFERENCES

[6.0.1] HI-STORM 100 FSAR, NRC Docket 72-1014, Holtec Report HI-2002444, Latest revision

[6.0.2] "Criticality Analyses for the HI-STORM FW System", Holtec Report HI-2094432 Rev.0 (proprietary)

[6.1.1] NUREG-1536, Standard Review Plan for Dry Cask Storage Systems, USNRC, Washington, D.C., January 1997.

[6.1.2] 10CFR72.124, "Criteria For Nuclear Criticality Safety."

[6.1.3] not used

[6.1.4] "MCNP - A General Monte Carlo N-Particle Transport Code, Version 5"; Los Alamos National Laboratory, LA-UR-03-1987 (2003).

[6.1.5] M.G. Natrella, Experimental Statistics, National Bureau of Standards, Handbook 91, August 1963.

[6.1.6] "CASMO-4 Methodology", Studsvik/SOA-95/2, Rev. 0, 1995.

"CASMO-4 A Fuel Assembly Burnup Program, Users Manual," SSP-01/400, Rev. 1, Studsvik Scandpower, Inc., 2001.

"CASMO-4 Benchmark Against Critical Experiments", Studsvik/SOA-94/13, Studsvik of America, 1995.

[6.4.1] J.M. Cano, R. Caro, and J.M Martinez-Val, "Supercriticality Through Optimum Moderation in Nuclear Fuel Storage," Nucl. Technol., 48, 251-260, (1980).

[6.4.2] NUREG/CR-7194, Technical Basis for Peak Reactivity Burnup Credit for BWR Spent Nuclear Fuel in Storage and Transportation Systems, USNRC, Washington, D.C., April 2015.

[6.4.3] HI-STAR 100 SAR, HI-951251 Revision 15, submitted with Holtec Letter 5014709, ML102880564