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# End Effect $K_{eff}$ Bias Curve for Actinide-Only Burnup Credit Casks

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## Introduction

A conservative end effect $k_{eff}$ bias curve for actinide-only burnup credit casks is presented in this paper. Rather than performing axially burnup-dependent analysis, cask designers can, if they choose to, analyze casks with a uniform axial burnup (at assembly average burnup value) and add the $k_{eff}$ bias values to conservatively bound the actinide-only end effect. Earlier studies[1-3] suggested 1 ~ 3 % increase in $k_{eff}$ to account for the end effect, but they included fission products as well as actinides for their analyses.



## Analysis

The key parameters of importance for end effect analysis are (1) axial burnup distributions, (2) burnups, (3) initial enrichments and (4) cask configurations (i.e., size and poison plate design). The normalized axial burnup distribution (18 equally spaced axial regions) used for the actinide-only end effect analysis is the following: 0.573, 0.917, 1.066, 1.106, 1.114, 1.111, 1.106, 1.101, 1.097, 1.093, 1.089, 1.086, 1.081, 1.073, 1.051, .993, 0.832, 0.512. This is the most limiting distribution in the high burnup range (46 to 50 GWD/MTU)[4] based on an axial burnup profile database prepared by Yankee Atomic Electric Company[5]. The range of burnups and enrichments considered are 10 to 50 GWD/MTU and 1.5 to 5.0 w/o, respectively. Three different radial models are employed to represent different cask configurations. They are: (1) infinite array of fuel pin cells to approximated a large cask, (2) transverse buckling dimension of 43 cm to approximate a small cask (i.e., GA-4[6]) and (3) transverse buckling dimension of 22 cm to approximate the presence of completely "black" poison plates around a single PWR assembly.

The standard Westinghouse 17 x 17 assembly design is used for both depletion and criticality calculations. The actinide isotopic concentrations are determined from SAS2H[7] depletion sequence. The axially burnup dependent analysis is performed using CSASIX/ WAX/XSDRNPM criticality calculation sequence in SCALE[7] code system. Slab geometry is used in specifying the transverse buckling dimensions of finite casks and axial reflectors are modeled with 30 cm of water.

## Results

Figure 1 shows maximum end effects (maximum of the initial enrichments considered) as a function of assembly average burnup for aforementioned three different cask configurations as well as a conservative end effect $k_{eff}$ bias curve. The first notable trend in Figure 1 is that the end effect increases with a decrease in cask sizes and a presence of poison plates. Therefore, a single PWR assembly with completely "black" poison plates around it can very well encompass the end

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effects expected in realistic cask designs. Figure 1 shows that the end effects are negative in the low burnup range. Positive end effects become apparent only after about 30 GWD/MTU even for a small cask like GA-4. Again, a single PWR assembly with completely "black" poison plates around it can be used to establish a conservative cross-over point, and Figure 1 shows that the burnup of 20 GWD/MTU is appropriate for this limiting cask configuration. The conservative end effect $k_{eff}$ bias shown in Figure 1, therefore, stays zero up to 20 GWD/MTU and gradually increases to 1.656 % $\Delta k_{eff}$ at 50 GWD/MTU. Finally, although not shown explicitly in Figure 1, it should be mentioned that there is no discernable end effect trend with respect to initial enrichments.

## Conclusions

The end effect is a strong function burnup and increases as the cask size decreases. Also, a presence of poison plates increases the end effect. A $k_{eff}$ bias curve, established based on the most limiting cask configuration of a single PWR assembly with completely "black" poison plates around it, conservatively bounds the end effects in realistic cask designs. Thus, axially uniform criticality calculations and subsequent application of the proposed $k_{eff}$ bias curve could eliminate the need for time-consuming axially burnup dependent analyses.

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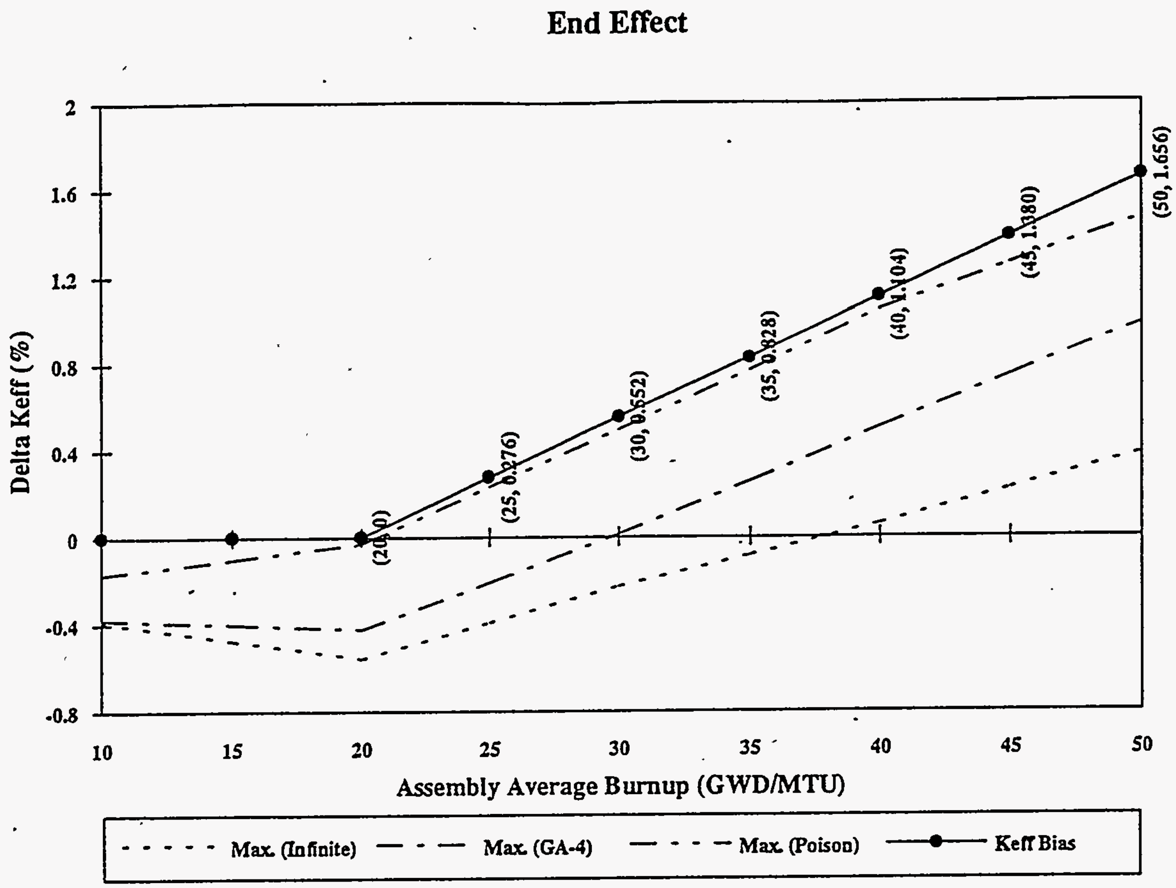


Figure 1. End Effect ($\Delta k_{eff}$) vs. Assembly Average Burnup (GWD/MTU)