Determination of a Depletion Uncertainty From Fuel Management Experience

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Historically the US NRC has allowed spent fuel pools to use 5% of the delta k of depletion as the depletion uncertainty. Recently, there have been requests from the NRC to show the basis of the uncertainty. This paper shows that commercial reactor fuel management experience can be used to justify an uncertainty of less than 2% of the delta k of depletion.

A commercial vendor and its customers have analyzed over 200 cycles of commercial power operation with current generation codes. The mean bias in the startup hot zero power ppm is 3 ppm, which is only 0.0003 in k. The standard deviation about the mean of these 200 startups is 13 ppm or 0.0013 in k. The mean volume averaged core burnup of these startups is 12.2 GWD/MTU. The range of the volume averaged core burnup of any of these 200 cases is 10.7 to 14.7 GWD/MTU. No trend with burnup has been observed.

As well as the startup predictions, this same vendor has documented (in-house) its capability to predict the HFP end of cycle reactivity with these same codes for 189 cycles. The mean end of cycle bias in reactivity is 0.0007 in k. The standard deviation about this condition is 0.0024. The mean volume averaged core burnup of these measurements is 21.3 GWD/MTU. The core average burnups ranged from 17.1 to 29.3 GWD/MTU. Again no significant trend has been observed with burnup.

Even though differences were observed, these differences are due to a combination of factors, such as the measurement uncertainty, errors in modeling, differences between the actual core conditions and the modeled conditions, and finally, errors in the delta-k due to depletion. For simplicity, it will be conservatively assumed that all the difference between the measured ppm and the predicted ppm is due to errors in the depletion. This is a very conservative assumption since there has been no observed trend with burnup, which implies that most, if not all, of the differences are due to factors that have nothing to do with burnup.

The delta k from enriched UO_2 to the average startup burnup of 12.2 GWD/MTU is 0.117 in k. Using data from the startup measurements and assuming that all of the differences are due to errors in the depletion, the bias is then 0.0003/0.117 or 0.3% of the delta k of depletion. The uncertainty in this bias is 0.0013/0.117 or 1.1% of the delta k of depletion. The same analysis can be done using the end of cycle reactivity measurements. Here the delta k from enriched UO_2 to the average end of cycle burnup of 21.3 GWD/MTU is 0.207 in k. The burnup bias from the end of cycle results is –0.0007/0.207 or 0.3% of the delta k of depletion. The uncertainty in this bias is 0.0024/0.207 or 1.2% of the delta k of depletion. The bias and uncertainties from both the startup predictions and the end of cycle predictions are very similar. To be conservative the higher bias and uncertainty is used. It is concluded that the fuel management tools have a bias that is less than 0.3% in the delta k of depletion and an uncertainty in this bias of less than 1.2% of the delta k of depletion.