Response to the NRC's Request for Additional Information on WCAP-10216-P-A, Revision 1A, Addendum 1, "FQ Surveillance Technical Specification: Axial Offset Validity and Part-Power Surveillance Guidance" (TAC No. MD9425) (Non-Proprietary)

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NRC RAI #1

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 6, why is the 1/P term limited to 1/0.5 for power levels below 50% of the rated thermal power?

Response to NRC RAI #1

The Technical Specification Bases for F_Q explain that, at less than or equal to 50% power, the F_Q limit is given by the full power limit divided by 0.5. The reason for this is historical. There is no technical reason for limiting the F_Q value in this way below 50% power. In fact, the F_Q limit could be higher below 50% power. The real limit is the maximum power density (e.g., maximum kW/ft) assumed in the safety analysis. The limit could have been formulated originally in terms of maximum allowed power density instead of F_Q. Some non-Westinghouse NSSS plants have maximum power density limits in terms of kW/ft not F_Q. For those plants, the kW/ft limit is not a function of power level. In practice, power levels below 50% will not be limiting because the F_Q limit is so large. Restricting the F_Q limit to twice the full power value below 50% power is conservative, but has no practical significance.

NRC RAI #2

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 8, how are the measured radial and axial components of the peaking factor that appear in equations 3.3 – 3.5 determined?

Response to NRC RAI #2

In F_Q surveillance, separation of the measured $F_Q(z)$ into its radial and axial components is not required to perform the surveillance. In practice, however, the measured three-dimensional core power distributions provide both the radial and axial components in addition to the total measured $F_Q(z)$.

The methods used to measure the core power distribution and to determine $F_Q^C(z)$ and its components are described in WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," and also in WCAP-12472-P-A, "BEACON – Core Monitoring and Operations Support System."

Briefly, a flux map is periodically taken at steady state core conditions. The measured three-dimensional core power distribution and peaking factors are determined using the measured detector reaction rates, obtained from the moveable detector system, and analytical power-to-reaction-rate ratios, obtained from the core model.

Once the measured three-dimensional core power distribution is obtained from the flux map, the steady state $F_Q(z)$, $F_{xy}(z)$, and $P(z)$ can be easily determined. $F_Q(z)$ is simply the peak local power density at axial elevation z divided by the average core power density. $F_{xy}(z)$ is the peak local power density at axial elevation z divided by the average power density of the core radial plane at elevation z. $P(z)$ is the core average axial power shape and is the average power density of the core plane at elevation z divided by the core average power density.

For plants using the BEACON™ Core Monitoring System[1], the BEACON core model is calibrated to the core using flux maps, excore detector measurements, and thermocouple measurements. The three-dimensional BEACON core model is then used to determine the $F_Q(z)$, $F_{xy}(z)$, and $P(z)$ factors.

NRC RAI #3

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 8 it states, "The ratio of measured to predicted steady state P(z) becomes a significant factor impacting the transient F_Q surveillance results when the measured target AO is different than the predicted target AO at the time of the surveillance. The parameter ΔAO (or "Delta-AO") is often used in describing such deviations, and is defined as follows for equilibrium surveillance conditions where the measured and predicted core power level and control rod insertion are consistent with one another:..." What is used to describe such deviations when the measured and predicted core power level and rod insertion are not consistent with one another? How does this other parameter fit into the F_Q surveillance?

Response to NRC RAI #3

The text was not meant to imply that some other factor is used to describe such deviations when the measured and predicted core power level and rod insertion are not consistent with one another. In cases where a surveillance is performed at part-power, for example, the measured axial power shape may differ significantly from the predicted full power axial power shape used in determining the W(z) factors. As a result, the measured axial offset may differ from the predicted axial offset, i.e., a Delta-AO may be present. Similarly, a surveillance performed with significant control rod insertion may result in the presence of a larger Delta-AO. This difference in power shape will affect the results of the transient F_Q surveillance in the same way as when a Delta-AO is present during a full power surveillance, i.e., the Delta-AO will cause the transient $F_Q(z)$ to be over-estimated in the over-powered half of the core and under-estimated in the under-powered half of the core. The implications of power shape deviations for part-power surveillances are discussed in Section 3.1 (page 11) of Addendum 1. As this section indicates, it is recommended that the AO be maintained near the axial offset used in generating the W(z) values (to ensure a Delta-AO near 0% for the surveillance) when a part-power surveillance is performed. Furthermore, to minimize the possibility of an overly conservative measurement for a part-power surveillance, W(z) values specific to the surveillance conditions (e.g., power level, axial offset, control rod position) may be generated.

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[1] BEACON™ is a trademark of Westinghouse Electric Company LLC in the United States and may be registered in other countries throughout the world. All rights reserved. Unauthorized use is strictly prohibited.

NRC RAI #4

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 9, what are the most significant approximations used in the nuclear models that would affect the W(z) functions, and how large could the discrepancies be?

Response to NRC RAI #4

The most significant approximations used in generating the nuclear models that could affect the W(z) values have to do with modeling the core operating history and conditions and with the local tracking of actinide number densities. When nuclear models are generated, the core is typically assumed to operate at hot full power, nominal flow, temperature, and pressure conditions, and all rods out through the entire cycle until end of full power capability. Nuclear models depleted in this fashion are then used to predict the steady-state $F_Q(z)$, which appears in the denominator of the W(z) expression. If the depletion history of the core differs from the assumption used to generate the models or if the operating conditions differ somewhat from the nominal values assumed, then small differences in axial offset and core average axial power shape can occur. Furthermore, the core average axial burnup distribution of the cycle N nuclear model will depend in part on the depletion history of cycle N-1. Thus, the depletion history of cycle N-1 affects the axial power distribution and axial offset predictions for cycle N. If the AO was not well predicted in cycle N-1 (i.e., a significant Delta-AO was present), it may affect the cycle N AO prediction because of these history effects. The above considerations typically result in Delta-AO values within [ ]^{a,c}, which is considered normal and consistent with historical experience. Such Delta-AO values could affect the W(z) values by up to approximately [ ]^{a,c}, depending upon the axial elevation. Axial locations near the middle of the core will be affected less than locations near the ends of the core.

Some cores have been observed to have Delta-AO values that exceed the [ ]^{a,c} normal range. Sometimes this occurs near the beginning of the cycle and has been attributed to approximations in the modeling of the fuel depletion isotopics, specifically the actinides (U, Np, Pu, etc.). Each point in the core has a unique flux spectrum history dependent in part upon its moderator density history. This spectrum history affects the fuel depletion isotopics. For example, core nodes near the top of the core will experience a smaller moderator density. The result of this is a larger fast-to-thermal flux ratio and increased rate of U-238 transmutation to Pu-239. Current Westinghouse nuclear models do not capture the effect of the unique spectrum history of each core node on the local actinide distribution. The resulting approximations in the fuel isotopics can sometimes lead to Delta-AO values in excess of [ ]^{a,c} at beginning of life. By using additional cross section sets axially in the nuclear model, however, a better approximation of the axial variation in the fuel isotopics is obtained since the fuel isotopics are tracked for each cross section set in the nuclear model. This has improved the AO performance such that most cores are within the [ ]^{a,c} normal Delta-AO range at beginning of life.

In cases where the above effects lead to larger Delta-AO values, the operating history assumptions and cross section models can be revised if necessary to improve the overall AO performance. However, since the effects of Delta-AO on F_Q margin are well understood, as described in Sections 4 and 5 of WCAP-10216-P-A, Revision 1A Addendum 1, it is often possible to assess the impact of a larger Delta-AO on the available F_Q margin without making any W(z) adjustments or by using the simplified adjustment methods described in Sections 5.1 and 5.2 of Addendum 1.

NRC RAI #5

In WCAP-10216-P-A the variable P is defined as the fraction of rated thermal power at the time the surveillance measurement is taken. On WCAP-10216-P-A, Revision 1A, Addendum 1, page 10, it is indicated that the W(z) function is to be divided by the quantity 1/P. This is not currently part of WCAP-10216-P-A nor the Standard Technical Specifications in NUREG-1431, Revision 3.1, "Standard Technical Specifications Westinghouse Plants". Why is it being proposed here? To demonstrate the acceptability of higher peaking factors at reduced RTP WCAP-10216-P-A and the Standard Technical Specifications in NUREG-1431, currently stipulate that for part power surveillances the F_Q^{Limit} is to be divided by P. At 50% RTP this has the effect of doubling the F_Q^{Limit}. Dividing W(z) by 1/P at 50% RTP would have the effect of cutting the W(z) function in half. Why is appropriate to cut the W(z) in half at the same time the F_Q^{Limit} is being doubled? Provide a detailed explanation.

Response to NRC RAI #5

The text on page 10 of Addendum 1 contains a misstatement. To clarify, the third sentence of the second paragraph should read as follows: "In a hypothetical scenario involving application of a HFP W(z) function to a part power $F_Q^W(z)$ surveillance, it is possible for the surveillance to over-estimate the available minimum transient F_Q margin if the surveillance relative power level, or a factor of 0.5 below 50% power, is not included in the denominator of the W(z) expression (i.e., if a relative power of 1.0, corresponding to full power, is assumed)."

Thus, there is no intent to cut the W(z) value in half. The misstatement on page 10 of Addendum 1 will be corrected in the approved version of the report.

NRC RAI #6

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 10, what is the magnitude of the conservatism implied in the following statement "--- using unadjusted W(z) functions will result in conservative estimations of the minimum margin available to the $F_Q(z)$ limit, when compared to performing the surveillance again with rigorously calculated W(z) functions"?

Response to NRC RAI #6

The full statement is as follows: "The RAOC sensitivity study also confirmed that the majority of $F_Q^W(z)$ measurements performed using unadjusted W(z) functions will result in conservative estimations of the minimum margin available to the $F_Q(z)$ limit, when compared to performing the surveillance again with rigorously calculated W(z) functions."

The magnitude of the conservatism referred to in the statement is dependent on the magnitude of the Delta-AO. This is illustrated in Table 4-1 and also Figure 4-1a of the Addendum. Table 4-1 gives minimum F_Q margin values obtained using unadjusted W(z) values and minimum F_Q margin values obtained using recalculated W(z) values (truth). The last column of Table 4-1 provides the surveillance margin decrease when unadjusted W(z) values are used. Negative values indicate that the unadjusted W(z) values produce a conservative surveillance, i.e., the true F_Q margin is underestimated. As Table 4-1 shows, the surveillance margin decrease is negative in a majority of the cases. Figure 4-1a shows this graphically. Note that the conservatism in the unadjusted W(z) values reached [ ]^{a,c} at a Delta-AO of [ ]^{a,c}

NRC RAI #7

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 11 it states, "Required confirmation of the minimum transient $F_Q^W(z)$ margin should be limited to surveillance powers greater than or equal to 50% RTP, since the AFD Technical Specification upon which the W(z) functions are based is not applicable below this power level." Since the F_Q surveillance is required at powers below 50% RTP, how is the surveillance to be conducted below 50% RTP? How is this requirement to be included in the technical specifications?

Response to NRC RAI #7

The Standard F_Q Surveillance Technical Specifications (NUREG-1431, Revision 3) require that the steady state and transient F_Q surveillances be performed prior to exceeding 75% power following a refueling outage. There is no specific requirement in the standard Technical Specifications to perform this first F_Q surveillance below 50% RTP. However, some utilities routinely include the F_Q surveillances as part of the lower power surveillances performed at less than 50% RTP to confirm core symmetry and to confirm that the nuclear enthalpy rise hot channel factor limit is met following a refueling outage. The purpose of the statement on page 11 of Addendum 1 is to suggest that the verification of the transient $F_Q^W(z)$ margin need not be included in these surveillances below 50% RTP, as long as verification is performed in a higher power surveillance prior to exceeding 75% power, because of the difficulty in obtaining an accurate assessment of the transient $F_Q^W(z)$ margin at such a low power level and since operation at such a low power level will not challenge the F_Q limit. Verification of the steady state $F_Q^C(z)$ is also not required below 50% RTP following a refueling outage, but this surveillance does not include any of the technical challenges inherent to the transient $F_Q^W(z)$ surveillance through application of the W(z) factor. The F_Q limit is only likely to be challenged through non-equilibrium operation at high power levels. Verification of $F_Q^W(z)$ at very low power levels is, therefore, unnecessary.

As stated in the Bases for the standard F_Q Surveillance Technical Specification, requiring that the F_Q surveillance be performed before exceeding 75% RTP "...ensures that some determination of $F_Q^C(z)$ and $F_Q^W(z)$ are made at a lower power level at which adequate margin is available before going to 100% RTP." Furthermore, the Standard Technical Specification requires that a surveillance be performed "once within 12 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified." Consequently, the Standard Technical Specification requires verification of $F_Q^W(z)$ at high power levels, once equilibrium conditions have been established, to confirm that future non-equilibrium operation will not challenge the transient F_Q limit. The approach being suggested on page 11 of Addendum 1 would have the utility perform the first transient $F_Q^W(z)$ surveillance following a refueling outage at a power level greater than or equal to 50% but less than 75% RTP, so that a more accurate and meaningful assessment of the transient F_Q margin can be made in the first F_Q surveillance performed following a refueling outage. No changes would be required to the current standard Technical Specifications to implement this proposed surveillance strategy.

NRC RAI #8

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 17, explain the "rebound effect" resulting from skewed axial burnup distributions from previous cycles, and how this leads to a positive ΔAO?

Response to NRC RAI #8

If a core operates with Crud Induced Power Shift (CIPS), the axial offset will be more negative than predicted by the nuclear model. Thus, the actual core axial power shape will be more negative than predicted causing the fuel assemblies in the core to accumulate more burnup in the bottom of the core relative to the top than predicted by the nuclear model. Roughly two-thirds of these fuel assemblies will be employed in the subsequent cycle. If the nuclear model for this subsequent cycle did not model the CIPS AO history of the previous cycle, it will not capture this perturbation to the axial burnup shape. In other words, the real core in the subsequent cycle will have a more bottom skewed axial burnup distribution than the modeled core. This will cause the real core to have a more top skewed power distribution than the modeled core at beginning of life; thus, there will be a positive Delta-AO. This is the "rebound effect." Note that CIPS will not be present at BOL, and so there is no forcing function to offset the power distribution effect of the axial burnup distribution perturbation.

NRC RAI #9

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 17, list the operating parameters that are varied, other than burnup, to produce the ΔAO variations in the [ ]^{a,c} cases considered in the sensitivity study?

Response to NRC RAI #9

In addition to perturbations to the axial burnup distribution, perturbations to the axial distribution of the B-10 number density in the fuel burnable absorbers were made to simulate Axial Offset Deviation. To simulate CIPS, [ ]^{a,c}

NRC RAI #10

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 17, the sensitivity analysis discussed on page 17 refers to [ ]^{a,c} cases, in the explanation of the terms in Equation 3.1 (page 5) reference is made to "several thousand" cases in developing the numerator of W(z). Are these two numbers referring to the same problem? Is the statistical accuracy implied by using [ ]^{a,c} cases high enough to result in the required accuracy and confidence?

Response to NRC RAI #10

The [ ]^{a,c} cases referred to are the Delta-AO cases listed, for example, in Table 4-1. These represent various perturbations to a base steady-state power shape and $F_Q(z)$ due to AOD, CIPS, or differences in the axial burnup shape. The "several thousand" predicted $F_Q(z)$ distributions referred to on page 5 of Addendum 1 are the result of transient power shapes determined using the RAOC methodology. These transient power shapes are meant to characterize the range of power shapes that could occur during normal operation within the allowed operating space. They comprise various combinations of power level, control rod insertion, xenon shapes, and AFD values.

A steady-state $F_Q(z)$ shape, corresponding to the expected surveillance condition at a given cycle burnup, is used in the denominator of the W(z) expression. The transient $F_Q(z)$ shapes for that given cycle burnup are used in the numerator of the W(z) expression. The W(z) ratio, then, characterizes the maximum expected increase in the steady-state $F_Q(z)$*Power at the surveillance condition due to future non-equilibrium operation within the allowed operating space.

The statistical significance of the [$]^{a,c}$ cases is discussed on page 18 of Addendum 1. As indicated there, this range of cases is large enough and diverse enough to conclude that a value of [$]^{a,c}$ will bound with high statistical confidence the maximum expected non-conservative transient F_Q surveillance margin value obtained using W(z) values which are unadjusted for the effects of a Delta-AO.

NRC RAI #11

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 18, is the sensitivity analysis presented in section 4.2 limited to plants characterized by the description on page 18? Will it be necessary to repeat the study if new plants are operated?

Response to NRC RAI #11

The sensitivity analysis presented is considered generic for plants employing RAOC and F_Q Surveillance. The key feature of RAOC is an AFD operating envelope that is fixed and independent of the natural axial offset of the core. It is this feature, rather than, for example, differences in core size or fuel design, that determines the sensitivity of W(z) values to Delta-AO.

In addition to those plants employing RAOC and F_Q Surveillance, there is another class of plants that exhibits sensitivity to Delta-AO values during peaking factor surveillances. Specifically, plants employing CAOC with F_{xy} Surveillance will have a similar sensitivity to Delta-AO as RAOC/F_Q Surveillance plants. The CAOC and F_{xy} Surveillance Technical Specifications are described in NUREG-1431, Revision 3. The results of the RAOC sensitivity analysis are considered applicable to this class of plant because $F_{xy}(z)$ Surveillance limits can be described mathematically to be a function of inverse W(z) surveillance factors. As a result, the methods identified for adjustment of W(z) factors in Sections 5.1 and 5.2 of WCAP-10216-P-A, Revision 1A, Addendum 1 can be modified appropriately and applied to $F_{xy}(z)$ Surveillance limits for CAOC plants experiencing Delta-AO.

In F_{xy} Surveillance, a maximum allowable $F_{xy}(z)$ value is specified in the Core Operating Limits Report. During a surveillance, the maximum F_{xy} value at each core height is measured (except for regions specifically excluded by the Technical Specification). By confirming that the measured $F_{xy}(z)$ is less than the maximum allowable $F_{xy}(z)$, the F_Q limit is verified to be met. The maximum allowable $F_{xy}(z)$ is derived from the $F_Q(z)$ limit and the maximum transient P(z) values obtained from the CAOC power shape analysis. While CAOC/F_{xy} Surveillance plants do not use W(z) values, it is possible to relate the maximum allowable $F_{xy}(z)$ values to the W(z) values determined for F_Q Surveillance.

The Maximum Allowable $F_{xy}(z)$ limit (with uncertainties) for a CAOC/F_{xy} Surveillance plant can be expressed as follows:

Maximum Allowable $F_{xy}(z) = F_Q^{Lim}(z) \,/\, [W(z) * P^{Prcd,BL}(z)\,]$

where $P^{Prcd,BL}(z)$ is the predicted axial power shape at the steady state surveillance condition (base load). The denominator of the above equation represents the maximum transient P(z) obtained from the CAOC power shape analysis. In practice, a constant grid penalty factor is usually included in the denominator of the above equation because predicted axial power shapes typically do not include the effect of slightly increased power peaking between the grid spans.

For CAOC plants, W(z) does not vary with Delta-AO, because the AFD limits move with the measured target AFD. Effectively the maximum transient power shapes vary in proportion to variations in the steady state target power shape. As a result, W(z), which is essentially just the ratio of the maximum transient and steady-state power shapes, remains constant with Delta-AO. This concept is briefly discussed at the bottom of page 6 of the Addendum and is illustrated in Figure 3-4 of the Addendum.

Since W(z) does not vary with the steady-state power shape for a CAOC plant, every term on the right hand side of the above expression is a constant except $P^{Prcd,BL}(z)$. So, to adjust the maximum allowable F_{xy} limits, we can just use the ratio of the predicted and measured power shapes, i.e.:

New Max. Allowed $F_{xy}(z)$ =[$P^{Prcd,BL}(z) \,/\, P^{Meas,BL}(z)$] * Original Max. Allowed $F_{xy}(z)$]

This is analogous to the Steady State P(z) Ratio Method for adjusting the W(z) values described in Section 5.2 of the Addendum. Effectively, in the overpowered half of the core, the maximum allowable F_{xy} value will decrease since the ratio of the predicted and measured steady state power shapes will be less than 1.0. This is appropriate since the effective transient P(z) will be larger in the overpowered half of the core. To compensate for this, the maximum allowable F_{xy} limit in the overpowered half of the core must be smaller. Conversely, in the underpowered half of the core, the maximum allowable F_{xy} limit will increase.

The [ ]^{a,c} Penalty Factor described in Section 5.1 of the Addendum is appropriate for CAOC/Fxy Surveillance plants as well. However, it is applied somewhat differently. This penalty factor is simply a conservative, simplified version of the Steady State P(z) Ratio Method. [

]^{a,c} In other words, the penalty factor is used to reduce the maximum allowable $F_{xy}(z)$ values in the overpowered half of the core. Consequently, when the measured F_{xy} values are compared against the adjusted F_{xy} limits in the overpowered half of the core, margin will be reduced.

Therefore, with minor modifications, the methods for accommodating a Delta-AO in RAOC/F_Q Surveillance plants can be employed for CAOC/F_{xy} Surveillance plants as well. The concepts discussed above have been tested and confirmed in a limited CAOC sensitivity analysis which was performed at Westinghouse. The CAOC sensitivity analysis was similar to the RAOC sensitivity analysis in that perturbed core models were generated with Delta-AO and the effect of rigorously re-calculating the $F_{xy}(z)$ Surveillance limits on margin was compared to using the correction methods described above.

Furthermore, the guidance provided in Section 4.3.2 of the Addendum with respect to review of safety analysis inputs and plant operational data is prudent for CAOC/F_{xy} Surveillance plants as well since any sustained Delta-AO will have history effects that should be evaluated, as should any large AO deviation between the model and the actual core.

NRC RAI #12

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 19, there are only [ ]^{a,c} plant C, 10,000 MWD/T burnup points on table 4-1, and [ ]^{a,c} points plotted on Fig. 4-1b. What points (combination of plant type and burnup) are plotted on Fig. 4-1b?

Response to NRC RAI #12

All [ ]^{a,c} points are for Plant C at 10000 MWD/MTU burnup. Only [ ]^{a,c} of the points are given in Table 4-1. The [ ]^{a,c} point is for a Delta-AO of 0%. This point is for the unperturbed model. For this 0% Delta-AO case, the unadjusted W(z) values represent "truth." Consequently, the true minimum F_Q margin in the core must exactly correspond to either the minimum margin value in the bottom half or the minimum margin in the top half of the core for this case (i.e., there is no over- or under-estimation of minimum margin since the Delta-AO is 0). As the figure shows, the minimum margin value in the bottom half of the core coincides exactly with the true minimum F_Q margin. The 0% Delta-AO data points exist for all plants and burnups analyzed in this study. They were omitted from Tables 4-1 through 4-3 in order to remove their influence on the calculated mean and standard deviations in the tables, and to provide the true number of perturbed models that were analyzed.

NRC RAI #13

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 19, how are the data points (top half of core, bottom half of core etc.) on Fig. 4-1b determined from the results shown in Table 4-1?

Response to NRC RAI #13

The data plotted in Figure 4-1b are not all included in Table 4-1. The points on the curve labeled "True Minimum F_Q Margin" can be found in Table 4-1 with the exception of the point for 0% Delta-AO, as discussed in the response to RAI #12. These points are from [ ]^{a,c} in Table 4-1. The "True Minimum F_Q Margin" points are taken from the "ΔAO" column (x-value) and the column labeled "Surveillance Minimum % F_Q Margin (Recalculated W(z)s)" (y-value).

Table 4-1 does not provide the minimum margin obtained using unadjusted W(z)s for both the top and bottom of the core. It only provides the minimum overall margin. These ordinate values are given in the Table 4-1 column labeled "Surveillance Minimum % F_Q Margin (No W(z) Change)" with the abscissa values given in the "ΔAO" column. For all Delta-AO values [ ]^{a,c}, the minimum margin value occurred in the bottom half of the core. Thus, these points are plotted on the curve labeled "Surveillance F_Q Margin with Unadjusted W(z) in Bottom Half of Core." For [ ]^{a,c}, the minimum F_Q margin using unadjusted W(z)s occurred in the top half of the core. Thus, [ ]^{a,c} is plotted on the curve labeled "Surveillance F_Q Margin with Unadjusted W(z) in Top Half of Core." The other non-limiting F_Q margin points in Figure 4-1b were obtained from the same calculations used to obtain the limiting points. In each case, they were simply the minimum margin values in the non-limiting half of the core.

NRC RAI #14

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 19, discuss the proportionality between F_Q and initial disparity implied in the following statement. "It can be shown based on the data in this study that the maximum possible magnitude of the non-conservatism in the F_Q surveillance measurement due to ΔAO in any particular case is proportional to [ ]^{a,c}, due to this phenomenon".

Response to NRC RAI #14

Consider a case where the F_Q^{Limit} is flat, i.e., the same value at all core elevations. Assume initially that the Delta-AO is 0%; therefore, the unadjusted W(z) values represent "truth." Suppose that the transient F_Q in the bottom half of the core just meets the limit so that the minimum F_Q margin is 0%. Suppose also that the minimum F_Q margin in the top half of the core is 5%. Because the limiting $F_Q(z)$ is in the bottom of the core, any negative Delta-AO will result in a conservative surveillance since a negative Delta-AO will increase power and the steady-state $F_Q(z)$ in the bottom half of the core. Multiplying this more bottom-skewed $F_Q(z)$ by the W(z) value will result in the F_Q exceeding the limit, i.e., negative margin. Thus, this would be a conservative surveillance since the true margin is 0%.

Next, consider what happens when the Delta-AO is positive. This will decrease the steady-state $F_Q(z)$ in the bottom of the core and increase it commensurately in the top. (If power is reduced in the bottom of the core, it must be increased on average by the same amount in the top to keep the core average power constant.) In the bottom of the core, then, instead of the margin being 0%, it will become more positive with increasing Delta-AO. In the top of the core, on the other hand, the margin will decrease from the initial value of 5% to smaller values with increasing Delta-AO. At some positive Delta-AO value, the margin in the top of the core and in the bottom of the core will be equal at about 2.5% each. For this case, [

]^{a,c} Any further increase in the Delta-AO would reduce the margin non-conservatism since the margin in the top of the core would get closer to 0%.

Now consider another scenario which is exactly the same as the one above but the initial margin disparity is 10%. In this case, [

]^{a,c}

NRC RAI #15

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 21, are these criteria limited to those conditions and combinations covered by the [ ]^{a,c} combinations analyzed in section 4.2?

Response to NRC RAI #15

The criteria on Addendum 1 page 21 are limited only to the extent that application of the second criterion is dependent on remaining within the bounds of Delta-AO and [ ]^{a,c} analyzed within the [ ]^{a,c} case study. The remaining plant characteristics and the specific combinations of plant conditions identified in Section 4.2 of the Addendum are not considered critical to the results. Given the range of cases that were studied, the results are considered generic to any RAOC cores employing F_Q surveillance.

The third criterion on page 22 of Addendum 1 will be applied when the Delta-AO and [ ]^{a,c} bounds of the [ ]^{a,c} case study are not met, or in cases where there is [ ]^{a,c} without any adjustments. Specifically, the procedures identified in Section 5 of Addendum 1 for performing a transient F_Q margin assessment during a particular surveillance, or W(z) adjustments, will be applied in these cases.

The [ ]^{a,c} case study demonstrated the acceptability of the simplified methods described in Sections 5.1 and 5.2 of Addendum 1 by comparing the results of their application to the more rigorous W(z) recalculation approach identified in Section 5.3. However, the historical experience at Westinghouse has indicated that the simplified approaches identified in Sections 5.1 and 5.2 are not limited to the plant conditions assumed in the [ ]^{a,c} case study, and would also provide acceptable results for any RAOC plant employing F_Q surveillance and experiencing a Delta-AO.

NRC RAI #16

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 21 it states, "Therefore, as long as the bounds of the study are not exceeded, a [$]^{a,c}$ allowance for F_Q margin will bound any non-conservatism in the transient F_Q surveillance measurements due to ΔAO conditions in RAOC plants. With that in mind,..." Provide a list and description of the 'bounds of the study.'

Response to NRC RAI #16

The bounds referred to are discussed in the previous sentence, specifically, the ΔAO range of [$]^{a,c}$ and [$]^{a,c}$. For example, if a core had a ΔAO of [$]^{a,c}$, it would be considered outside the bounds of the study.

NRC RAI #17

On WCAP-10216-P-A, Revision 1A, Addendum 1, pages 22-23, are these guidelines dependent on the specifics of the [$]^{a,c}$ conditions analyzed above in section 4.2?

Response to NRC RAI #17

No. The guidelines in Section 4.3.2 of the Addendum are not directly related to the [$]^{a,c}$ cases employed in this study. These guidelines were simply established as a matter of prudence to require an evaluation of the continued applicability of the reload safety analyses and operational data when the core has deviated significantly from the models employed in the original analyses. The expected result of this kind of evaluation is that the original analyses and operational data will continue to apply.

NRC RAI #18

On WCAP-10216-P-A, Revision 1A, Addendum 1, page 32, it is suggested that the "Steady State P(z) Ratio Method" not be applied to CIPS cores. Does this caution also apply to cores suffering from IFBA induced power shift, described in section 4.1?

Response to NRC RAI #18

No. IFBA induced power shift was included in the sensitivity studies performed. The results indicated that the maximum transient $F_Q(z)$ is not sensitive to the Delta-AO caused by the IFBA induced power shift. On the other hand, for CIPS cores some sensitivity was observed.

IFBA induced power shift is caused by a redistribution of the IFBA fuel pellet coating during the pellet loading process. In effect, more absorber is placed in the top of the fuel rod and less in the bottom relative to the intended absorber distribution. When this IFBA distribution is considered in combination with the range of xenon shapes generated in the RAOC analysis, the resulting range of permissible power shapes (i.e., power shapes that lie within the allowable axial flux difference envelope) is not significantly affected.

By contrast, CIPS results in more absorber being added only to the upper half of the core through deposition of B-10 in the crud. As a result, a slightly different set of permissible power shapes results when this B-10 distribution is considered in combination with the xenon shapes from the RAOC analysis. Some of these power shapes will be more limiting, especially in the middle of the core. Consequently, the transient $F_Q(z)$ will have a somewhat different shape for a CIPS core than for the same core without CIPS.