WCAP-17661-NP-A
Revision 1

February 2019

Improved RAOC and CAOC F_Q Surveillance Technical Specifications

Westinghouse

WCAP-17661-NP-A
Revision 1

Improved RAOC and CAOC F_Q Surveillance Technical Specifications

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February 2019

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This work was performed under PWROG program PA-LSC-0795.

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NRC FINAL SAFETY EVALUATION

This section contains the following documents:

1. NRC cover letter, "Final Safety Evaluation for Pressurized Water Reactor Owners Group Topical Report WCAP-17661, Rev. 1, 'Improved RAOC and CAOC FQ Surveillance Technical Specifications' (CAC NO. MF3348)," dated November 23, 2018.

2. "Final Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Pressurized Water Reactor Owners' Group Licensing Topical Report WCAP-17661, 'Improved RAOC and CAOC FQ Surveillance Technical Specifications' (Project NO. 694)"

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

November 23, 2018

Mr. W. Anthony Nowinowski, Program Manager
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

SUBJECT: FINAL SAFETY EVALUATION FOR PRESSURIZED WATER REACTOR OWNERS GROUP TOPICAL REPORT WCAP-17661, REV. 1, "IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS" (CAC NO. MF3348)

Dear Mr. Nowinowski:

By letter dated January 2, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14009A092), the Pressurized Water Reactors Owners Group (PWROG), submitted Topical Report (TR) WCAP-17661, Rev. 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications" to the U.S. Nuclear Regulatory Commission (NRC) for review and acceptance for referencing in regulatory actions. The TR was supplemented by letters dated September 13, 2016, and February 15, 2018 (ADAMS Package Accession Nos. ML16291A531 and ML18053A269, respectively). The TR provides the technical basis for updates to Technical Specification (TS) 3.2.1, "Heat Flux Hot Channel Factor," as presently contained in NUREG-1431, "Standard Technical Specifications – Westinghouse Plants" (ADAMS Accession Nos. ML12100A222 (Volume 1) and ML12100A228 (Volume 2)).

By letter dated April 24, 2018 (ADAMS Package Accession No. ML18081A006), the NRC staff provided the draft Safety Evaluation (SE) to the PWROG for proprietary review and factual error clarification. By letter dated August 2, 2018 (ADAMS Accession No. ML18318A324), the PWROG provided comments on the draft SE. The NRC staff draft SE comment disposition table is included as an attachment to this letter (ADAMS Accession No. ML18298A326).

Based on the review described in the enclosed final SE and subject to the limitations provided in Section 5.0, the NRC staff has determined that the RAOC and CAOC surveillance formulations and required actions proposed in WCAP-17661, Rev. 1 are acceptable for referencing in regulatory actions. The TR may be considered approved for use by the NRC staff, for the purpose of justifying the TS changes contained therein.

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W. Nowinowski - 2 -

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in licensing action requests, our review will ensure that the material presented applies to the specific plant involved. Requests for licensing actions that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that the PWROG publish an approved proprietary version of TR WCAP-17661-P, Rev. 1 within 3 months of receipt of this letter. The approved version shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The approved versions shall include an "-A" (designating approved) following the TR identification symbol.

As an alternative to including the requests for additional information (RAIs) and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and if the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, PWROG will be expected to revise the TR appropriately or justify its continued applicability for subsequent referencing. Licensees referencing this TR would be expected to justify its continued applicability or evaluate their plant using the revised TR.

Sincerely,

Dennis C. Morey, Chief
Licensing Processes Branch
Division of Licensing Processes
Office of Nuclear Reactor Regulation

Project No: 99902037

Enclosure:
Final Safety Evaluation ~~(Proprietary)~~

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FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO PRESSURIZED WATER REACTOR OWNERS' GROUP

LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

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Enclosure

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RELATED TO PRESSURIZED WATER REACTOR OWNERS' GROUP

LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

1.0 INTRODUCTION

The Pressurized Water Reactor Owners Group (PWROG) submitted Topical Report (TR) WCAP-17661[1] for U.S. Nuclear Regulatory Commission (NRC) staff review by letter dated January 2, 2014 (Ref. 1). The TR provides the technical basis for updates to Technical Specification (TS) 3.2.1, "Heat Flux Hot Channel Factor," as presently contained in NUREG-1431, "Standard Technical Specifications – Westinghouse Plants" (Ref. 2). Specifically, the TR addresses (1) potential non-conservatisms in Required Action B.1 of TS 3.2.1B, which is applicable to Relaxed Axial Offset Control (RAOC) plants, and (2) "the sensitivity of the formulation of the associated Surveillance Requirement (SR) to the differences between the measured and predicted surveillance power shapes at both nominal and part power conditions" (Ref. 1). The TR was supplemented by letters dated September 13, 2016 (Ref. 3) and February 15, 2018 (Ref. 4). The supplements provided responses to the NRC staff requests for additional information (RAIs).

In addition to the changes described above, WCAP-17661 includes several other improvements to Versions B and C of TS 3.2.1. TS 3.2.1B is the version that is applicable to plants that have implemented the RAOC methodology, whereas TS 3.2.1C is the version that is applicable to plants that use the Constant Axial Offset Control (CAOC) – W(Z) methodology. Meanwhile, TS 3.2.1A, the version of the TS that is applicable to plants using the CAOC-F_{XY} methodology remains unchanged, and this TR does not apply to such plants.

All of the TS changes described and justified in WCAP-17661 are described in detail in Section 3.0 of this safety evaluation (SE).

1.1 BACKGROUND: POWER DISTRIBUTION TERMS

The TR relates to peaking factors that are used to describe the power distribution at Westinghouse Electric Company (Westinghouse)-designed plants. These factors, and the various functions, factors, and limits that are used to manipulate the peaking factors in order to ensure they provide appropriate margins for uncertainties and operational transients over a given surveillance interval, are summarized in Table 1, located in the appendix to this SE. The table first defines the peaking factors, then provides the limits, functions, and multipliers, and finally provides definitions for the various different versions of each peaking factor.

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[1] As noted in the citation for Reference 1, WCAP-17661 exists in both proprietary (WCAP-17661P) and publicly available (WCAP-17661NP) formats. This SE is applicable to both formats, and refers to the TR generally without the proprietary designator (i.e., WCAP-17661).

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It is useful to refer to Table 1 alongside subsequent sections of this SE, in which the terms contained in the table are frequently used in discussing the algebraic formulations of the surveillance terms and operating limits.

1.2 PURPOSE OF TOPICAL REPORT

In 2009, Westinghouse identified a non-conservatism associated with the TS for the Heat Flux Hot Channel Factor ($F_Q(Z)$) for Westinghouse nuclear power plants. Specifically, it was recognized that the Required Actions in NUREG-1431 (Ref. 2), in situations where the plant does not meet an F_Q limit, are not as conservative as previously understood.

Westinghouse issued Nuclear Safety Advisory Letter (NSAL) 09-5, "Relaxed Axial Offset Control F_Q Technical Specification Actions," to address the situation on an interim basis (Ref. 5). The NSAL required four specific actions, in addition to the current specific Required Actions contained in the plant-specific F_Q TSs, if it was determined that F_Q was not within the Limiting Condition for Operation (LCO) limit following a surveillance performed at ≥ 75 percent rated thermal power (RTP). These actions are very conservative so that they envelop all plants.

Another potential non-conservatism becomes apparent in plants using RAOC rather than CAOC. A key surveillance parameter, $F_Q^W(Z)$, is the product of analytical factors and surveillance measurements. The analytical factors are derived before each reload, and must assume a reference condition for the surveillance, even though the surveillance takes place after the plant returns to power, and hence, well after the analytical factors are derived. The initial surveillance condition is not necessarily the same as the reference condition, and this can lead to an inaccuracy that is non-conservative.

The PWROG submitted WCAP-17661 in order to develop a permanent resolution to the problem and define appropriate revisions to the standard TS (STS) related to the F_Q surveillance. The intent is to replace the temporary actions required by the NSAL in case F_Q is found outside the LCO limits with Required Actions that will assure that plant operation will remain bounded by the facility safety analyses. The PWROG submitted WCAP-17661 to the NRC, requesting approval in order to make subsequent changes to the STS, NUREG-1431. The specific TS that are proposed to be changed are TS 3.2.1B, Heat Flux Hot Channel Factor (F_Q (Z) (RAOC-W(Z) Methodology)) and TS 3.2.1C, Heat Flux Hot Channel Factor (F_Q (Z) (CAOC-W(Z) Methodology)).

1.3 SUMMARY OF CHANGES

The following discussion provides a brief summary of the changes set forth in WCAP-17661. A detailed discussion of each change is provided in Section 3.0 of this SE, and a summary of changes in tabular format is provided in Table 2, in the appendix.

1.3.1 Limiting Conditions for Operation (Unchanged)

The LCOs for TS 3.2.1B and 3.2.1C remain unchanged. The requirement, in both versions of the LCO, remains for $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, to remain within the limits specified in the core operating limits report (COLR). The approximations for these parameters, however, will change as discussed in the succeeding sections.

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1.3.2 Core Operating Limits Report Content

Based on the discussion contained in the TR, the NRC staff determined that the typical COLR content[2] will change. As outlined below, the amount of the COLR content related to $F_Q^W(Z)$ will increase. Primarily, this increase stems from the following items, which will be newly included in the COLR:

1. The definition of new RAOC operating spaces (ROSs) or CAOC operating spaces (COSs),

2. The inclusion of a normalization factor $A_{XY}(Z)$ for RAOC, or $A_Q(Z)$ for CAOC,

3. The definition of a penalty factor, R_j, and

4. The inclusion of separate control rod insertion limits, transient functions, penalty factors, and axial flux difference (AFD) bands for the new ROSs and COSs.

The COLR will also include newly formulated, cycle-specific limits associated with implementing the proposed Required Actions to take in the event that completion of a SR indicates that an LCO is not met.

1.3.3 Surveillance Requirements

For RAOC plants, rather than formulating the $F_Q^W(Z)$ surveillance parameter by using a core-wide, three-dimensional surveillance to measure F_Q, the surveillance will now determine a synthesized F_Q using a planar F_{XY} surveillance and multiplying it by a reference axial power shape. The surveillance is repeated for each plane in the core, from 15- to 85-percent core height to determine a maximum to compare to the limit.[3] The philosophy of using multipliers to the measured value to provide margin for manufacturing tolerances, surveillance uncertainty, and operational transients over the following surveillance interval remains unchanged. However, the formulation of the transient function is modified.

In addition, some language contained in the SRs has been modified to add clarity, and minor changes to some surveillance frequencies have been proposed.

1.3.4 Required Actions

The Required Actions associated with both $F_Q^W(Z)$ and $F_Q^C(Z)$ have been modified. These modifications serve two primary purposes: (1) to provide more explicit limitations on thermal power and reactor trip setpoints in the condition that the SRs are not met, and (2) to

[2] This list was formulated by reviewing a sample of COLRs submitted on several dockets. The content of a specific COLR varies from plant to plant, and not all plants may have the exact content listed here.
[3] Per NUREG-1431, "The top and bottom 15-percent of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions" (Ref. 2, Volume 2, SR 3.2.1.2). Note that the top and bottom 15-percent exclusion zones are typical, however, the exclusion zone is established on a cycle specific basis to ensure that the limiting margin location is surveilled. Therefore, for a specific operating cycle, exclusion zones smaller than 15-percent may be specified.

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accommodate the implementation of successively restrictive operating spaces in the event that the SRs are not met.

2.0 REGULATORY EVALUATION

The specification of and adherence to limits on F_Q ensures that the value of the initial total peaking factor assumed in the accident and transient analyses remains valid. As noted in NUREG-1431, the F_Q limits assumed in the emergency core cooling system (ECCS) performance evaluation are typically limiting relative to the F_Q limits assumed in safety analyses for other postulated accidents and anticipated operational occurrences. Even if the ECCS limits are less limiting than those determined by another safety analysis, specification of and adherence to the F_Q limits still ensures that facility operation remains bounded by the safety analyses.

The regulatory evaluation thus identifies performance requirements and design criteria contained within Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities." The applicable requirements related to the specific content of TSs, relative to the facility safety analysis, are also identified, including appropriate guidance for administratively controlling such specifications. Finally, Section 2.3 of this SE summarizes the way in which the regulatory requirements apply specifically to the reformulated TS for F_Q.

2.1 PERFORMANCE REQUIREMENTS AND DESIGN CRITERIA

The performance requirements and design criteria applicable to the power distribution assumed in the safety analysis are those that pertain to accident and transient analysis. Primarily these include the requirements contained in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," and General Design Criterion (GDC) 10, contained in Appendix A, "General Design Criteria for Nuclear Power Plants." Since the TS also prescribe appropriate remedial action to follow if TS limitations are not met, some additional GDCs relative to the reactor protection and reactivity control systems also apply, as listed below.

The requirements in 10 CFR 50.46 state, in part, that ECCS shall be designed such that an evaluation performed using an acceptable evaluation model demonstrates that acceptance criteria, set forth in 10 CFR 50.46(b), including peak cladding temperature, cladding oxidation, hydrogen generation, maintenance of coolable core geometry, and long-term cooling are met for a variety of hypothetical loss-of-coolant accidents (LOCAs), including the most severe hypothetical LOCA.

GDC 10, "Reactor Design," states as follows:

> The reactor and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

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GDC 20, "Protection System Functions," states as follows:

> The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety.

GDC 26, "Reactivity Control System Redundancy and Capability," states as follows:

> Two independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions.

2.2 TECHNICAL SPECIFICATIONS

The requirements for TS are set forth in 10 CFR 50.36, "Technical Specifications." Specific categories of TS are provided in 10 CFR 50.36(c). These include LCOs and SRs. If an LCO is not met, the facility must be shut down, or other acceptable remedial action must be taken. SRs are intended to ensure that facility operation remains within the LCOs. NRC Generic Letter (GL) 88-16, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," established the NRC position that licensees could remove the cycle-specific values of certain operating limits from the TS and maintain them in a COLR, provided that certain requirements were met (Ref. 6).

Paragraph (c)(2) of 10 CFR 50.36 discusses LCOs, stating that such TSs are the lowest functional capability or performance levels of equipment required for safe operation of the facility. The requirements indicate that LCOs must be established for each item that meets one or more of four criteria. One of the criteria is a process variable, design feature, or operating restriction that is an initial condition of a design-basis accident (DBA) or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

Paragraph (c)(3) of 10 CFR 50.36 states:

> Surveillance requirements are requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the LCOs will be met.

The guidance contained in GL 88-16 provides a means by which the values of certain parameters could be determined and modified on a cycle-specific basis without prior NRC

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review and approval. In order to implement this guidance, licensees are required to do the following: (1) use NRC-approved methodology to determine the operating limits; (2) include a list, in the TS Administrative Controls section, of the references used to determine the operating limits; and (3) maintain the limits in a COLR, which must be submitted to the NRC for information.

2.3 DISCUSSION

The safety analyses required to establish that a facility will comply with the requirements of 10 CFR 50.46, and with GDC 10, require as input the peak fuel power and the power distribution. Since the peak power and the power distribution are initial conditions of DBA and transient analyses, facility operation must be controlled by LCOs that are established based on these parameters. Hence, Westinghouse pressurized water reactors (PWRs) have LCOs relative to F_Q. In accordance with 10 CFR 50.36(c)(2), the LCO is accompanied by SRs to ensure that the LCO is satisfied. At plants that have implemented GL 88-16, specific parameter values may be administratively controlled, and in such cases these parameters must be determined in accordance with NRC-approved methodology, and contained in the facility COLR.

If, during performance of an SR, F_Q is determined not to be within the limit then the LCO is not met, and the TS remedial actions must be followed to ensure that facility operation remains safe. These remedial actions are based on (1) restoring compliance with the LCO, and (2) adjusting the reactor protection system settings so that the functionality required by GDCs 20 and 26 is maintained.

The NRC staff evaluation of the modified TS contained in WCAP-17661 considered whether the modified TS are consistent with the regulatory requirements identified above. In particular, the NRC staff evaluated whether (1) the revised TS LCOs ensure that facility operation remains within the bounds established by the safety analysis, (2) the reformulated SRs ensure that facility operation meets the LCOs, and (3) the revised required actions and completion times, applicable if either or both of the LCOs are not met, are appropriate to ensure that compliance with the unmet LCOs is restored, and that facility operation remains safe.

3.0 DETAILED SUMMARY OF CHANGES

This section expands on the discussion provided in Section 1.3 of the SE.

3.1 IMPROVED METHODOLOGY TO DEFINE RAOC AND CAOC F_Q SURVEILLANCE

The current $F_Q(Z)$ surveillance relies on a combination of analytical factors and periodic measurements to provide assurance that core operation does not lead to unacceptable local power peaking. This works well for CAOC plants but for RAOC plants the approach is not as robust. Specifically, the problem is that prior to each reload when the analytical factors are calculated, there has to be a prediction of the axial power shape at the time of surveillance and this is usually not known.

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To understand how the new methodology is expected to overcome this problem, consider how the following F_Q surveillance parameter is defined:

$$F_Q^W(Z) = W(Z)[F_Q(Z)]_{Surv}^M * U_F \tag{1}$$

where *W(Z)* is an analytically derived factor and the *$F_Q(Z)$* in the brackets is the measured value (*M*) at the time of the surveillance (*Surv*). An uncertainty factor *U_F* is also added to this equation to account for both measurement and fuel manufacturing uncertainties. $F_Q^W(Z)$ must be less than or equal to a limiting value found in the COLR. It is related to the $F_Q^C(Z)$ surveillance parameter important to monitor steady state operation:

$$F_Q^W(Z) = W(Z) * F_Q^C(Z) \tag{2}$$

The analytically derived factor $W(Z)$ {

} is relative to a reference condition. It is calculated prior to operation of a cycle and found in the COLR for use during the surveillances.

$$\left\{ \qquad\qquad \right\} \tag{3}$$

where {

}. The denominator is the predicted (*p*) steady state value at the reference (*ref*) core condition. The latter is typically at hot full power with all control rods out and equilibrium xenon, which are not necessarily the conditions at which the surveillance F_Q is measured.

If the reference condition in Equation (3) is identical to the surveillance value in Equation (1) then the surveillance is done correctly, but if it is not, an error can be introduced. The new methodology replaces the factors in Equation (1) with equivalent factors which do not have the overt dependence that the reference and surveillance axial distributions are identical. The new surveillance parameter is derived in detail in WCAP-17661. It is[4]

$$F_Q^W(Z) = \frac{[T(Z)]^{COLR}}{P_{rel}^{SS}} A_{XY}(Z) * [F_{XY}(Z)]_{SURV}^M * U_F * R_j \tag{4}$$

Equation (4) uses both new analytical factors and new surveillance factors. The equation also includes a new penalty factor R_j. In this equation *$[T(Z)]^{COLR}$* is the pre-calculated function

$$\left\{ \qquad\qquad \right\} \tag{5}$$

[4] Only the situation for surveillance done above a relative power of 0.5 (i.e., 50-percent RTP) is considered herein. The situation below this power is an obvious extension and is given in WCAP-17661.

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where $[P(Z)]^{P}_{ref}$ is the relative axial power predicted at the reference condition. P^{ss}_{rel} is the relative power level (actual power divided by the RTP) at the time of the surveillance. An additional analytical factor A_{XY} is included in Equation (4) to account for differences between the reference and surveillance conditions:

$$\left\{ \qquad\qquad \right\} \tag{6}$$

The proposed approach (Equation (4)) is made consistent by using the measured $F_{xy}(Z)$ rather than $F_Q(Z)$ as in Equation (1) or (2). There is also the same factor U_F as in Equation (1) to take into account uncertainties.

The penalty factor R_j for surveillance time point j is used to account for the expected decrease in margin due to non-equilibrium operation over the period of operation prior to the next performance of SR 3.2.1.2.

The above approach to redefine the surveillance parameter factors is not needed for CAOC plants. However, analogous changes are proposed to the surveillance equation for CAOC plants to adjust for differences in the reference and surveillance conditions, and to implement the same penalty R_j for any expected decrease in margin prior to performing the next surveillance. The result changes the CAOC surveillance parameter from that shown in Equation (2) to the following:

$$F_Q^W(Z) = \frac{[W(Z)]^{COLR}}{P^{ss}_{rel}} * A_Q(Z) * [F_Q(Z)]^M_{Surv} * U_F * R_j \tag{7}$$

where the adjustment ratio is:

$$\left\{ \qquad\qquad \right\} \tag{8}$$

According to WCAP-17661, the usual case is that surveillances are performed at core conditions close to the conditions corresponding to the target axial offset measurement and hence, $A_Q(Z)$ will be very close to 1.0.

3.2 PROPOSED CHANGES TO TECHNICAL SPECIFICATIONS 3.2.1B AND 3.2.1C

The improved methodology for F_Q surveillance was used to define a number of changes to both RAOC and CAOC F_Q surveillance, i.e., both TS 3.2.1B and TS 3.2.1C are proposed to be revised. One obvious change is to substitute T(Z) for W(Z) in the title of TS 3.2.1B. A summary of the other proposed changes in each TS is given below and further summarized in Table 2.

3.2.1 Changes to the NOTE and Required Actions for Condition A: $F_Q^C(Z)$ not Within Limit

Changes are considered for the NOTE to Condition A and for Required Actions A.2 and A.3. The Changes are the same for both RAOC and CAOC plants.

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The NOTE for Condition A stated, "Required Action A.4 shall be completed whenever this Condition is entered." It is proposed to be changed as follows:

> Required Action A.4 shall be completed whenever this Condition is entered *prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.*

When $F_Q^C(Z)$ is not within limit, the Required Actions were defined as follows:

(1) Reduce thermal power ≥ 1% RTP within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$) prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The wordings in the Required Actions A.2 and A.3 which specify the magnitude of the setpoint reductions are proposed to be modified to account for the possibility that the limit for $F_Q^C(Z)$ is exceeded during a part-power surveillance.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) Reduce thermal power ≥ 1% RATED THERMAL POWER within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1* within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required action A.1* within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(Z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$ prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The Completion Times associated with these Required Actions were not revised.

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With the proposed change, when the limit for $F_Q^C(Z)$ is exceeded, thermal power will be limited to less than the surveillance power level required by Required Action A.1. The corresponding setpoints will therefore reflect this new thermal power limit. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, then thermal power will be limited to ≤ 74 percent RTP. Consequently, the new wording will require setpoint reductions of ≥ 26 percent since this is the amount by which the thermal power is limited below the RTP. The current Required Action wording would only require a setpoint reduction of ≥ 1 percent. In other words, the current requirement did not account for surveillance conducted at reduced power.

3.2.2 Changes to the Required Actions and NOTE for Condition B: $F_Q^W(Z)$ not Within Limit

The Required Actions for Condition B are different for RAOC and CAOC plants. Both are proposed to be revised in the improved F_Q TSs.

3.2.2.1 Proposed changes for RAOC plants

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."

In addition, there was a NOTE to Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved F_Q TSs, pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be in the COLR with characterized transient factors (T(Z) functions) which, in conjunction with the radial peaking factors, may be used to quantify the margin and ensure compliance with the LCO for future non-equilibrium operation. An RAOC operating space is a unique combination of an AFD operating space envelope and control rod bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient F_Q margin, minimum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the reduction is included in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

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(1) *Implement a RAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER and reduce AFD limits as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is changed to "Prior to increasing THERMAL POWER above the *limit of Required Action B.2.1.*"

The NOTE to Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "*Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1.*"

3.2.2.2 Proposed changes for CAOC plants.

The changes to the TS for CAOC plants (TS 3.2.1C) are similar to those for the TS of RAOC plants (TS 3.2.1B). However, the current requirements for these two types of plants are slightly different.

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that $F_Q^W(Z)$ exceeds limit (Required Action B.3). The associated Completion Time is 72 hours.

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(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the limit of Required Action B.1."

In addition, there was a NOTE to Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved CAOC F_Q TSs, a new Required Action B.1.1 is proposed which requires implementation of a new CAOC operating space, specified in the COLR, which restores $F_Q^W(Z)$ to within its limits. A CAOC operating space is a unique combination of CAOC AFD band limits and control rod bank insertion limits. A more restrictive CAOC operating space limits the range of possible non-equilibrium power shapes more than the current CAOC operating space through a smaller AFD band and/or shallower control rod insertion limits. The smaller CAOC operating space results in more transient F_Q margin. Alternatively, instead of implementing a more restrictive CAOC operating space, thermal power may be limited to some maximum value as specified in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) *Implement a CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, Implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is "Prior to increasing THERMAL POWER above the limit of Required Action B.2.1."

In addition the NOTE to Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed *prior to increasing the THERMAL POWER above the limit of Required Action B.2.1.*"

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3.2.3 Changes to Surveillance Requirements

The SRs are modified by a NOTE. The NOTE states the following, "During power escalation at the beginning of each cycle, thermal power may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."

The NOTE to the SR is proposed to be eliminated because it was considered to have been a source of confusion and can be interpreted differently by different utilities implementing the requirement.

3.2.4 Changes to Surveillance Requirements for $F_Q^C(Z)$: SR 3.2.1.1

The current SRs for $F_Q^C(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.1 requires verification that $F_Q^C(Z)$ is within its limits and it must be verified at the specified Frequency:

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 effective full power days (EFPD) thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In the improved F_Q TS, the second Frequency is proposed to be revised to require verification within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period to perform the verification.

3.2.5 Changes to Surveillance Requirements for $F_Q^W(Z)$: SR 3.2.1.2

The current SRs for $F_Q^W(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.2 requires verification that $F_Q^W(Z)$ is within its limits and it must be verified at the specified Frequency (same as $F_Q^C(Z)$):

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 EFPD thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In addition, there is a NOTE which modifies the SR as follows:

"If measurements indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$:

(1) Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or

(2) Repeat SR 3.2.1.2 once per 7 EFPD until either a., above, is met, or two successive flux maps indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has not increased."

The revised SR 3.2.1.2 modifies the first and second Frequency (items (1) and (2) above) and eliminates the NOTE.

The first Frequency is modified to be conducted following each refueling within [24] hours after thermal power exceeds 75 percent RTP.[5] This change is justified based on multiple reasons:

- Initial startups are not expected to result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit since initial startups are slow and are generally tightly controlled due to startup ramp rate limitations and fuel conditioning requirements.
- Core power distribution measurements taken at low power (<50 percent RTP) to confirm that the core is loaded properly will provide ample indications that the core is operating consistent with the expectations.
- Surveillances performed at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75 percent RTP will ensure that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium conditions could be limiting.
- Power levels of ≤ 75 percent RTP are non-limiting for minimum transient $F_Q^W(Z)$ margin. Performing the surveillance within 24 hours after thermal power exceeds 75 percent RTP will assure verification prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

The second Frequency is modified in the same way as SR 3.2.1.1 discussed earlier. It is proposed to require verification of $F_Q^W(Z)$ within 24 hours (instead of 12 hours) after achieving the equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period in which to confirm that $F_Q^W(Z)$ is within its limits given the extremely small likelihood of

[5] In Reference 7, a final modification was made to this Frequency to eliminate the italicized portion of the phrase "...within [24] hours *after achieving equilibrium conditions* after thermal power..."

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limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The NOTE is eliminated, but the application of the penalty factor remains because it is in the $F_Q^W(Z)$ formulation in the improved methodology for F_Q Surveillance. The required penalty factor, referred to as R_j in the new formulation, will be included in the COLR and will be tied to a predicted decrease in the actual transient F_Q margin in the upcoming time period prior to the next performance of SR 3.2.1.2 rather than a measured increase in the value of $F_Q^C(Z)$/K(Z) over the previous time period. When the transient F_Q margin is predicted to increase, the COLR will indicate an R_j factor of 1.0 (i.e., no penalty). When the margin is predicted to decrease, the COLR will indicate an appropriate R_j factor based on the predicted margin trends.

3.3 ATTRIBUTES AND IMPROVEMENTS OF REVISED F_Q SURVEILLANCE METHOD

The following seven attributes/improvements were provided in the response to RAI 13b, which asked for a discussion of the changes in the TSs and their relation to the improved methodology. This list provides a good summary of what is being accomplished by the change.

(1) The formulation for determining the measured transient $F_Q^W(Z)$ in RAOC plants has been revised to be less sensitive to the ability to predict the actual steady state axial power shape conditions where the surveillances are performed.

This is related to the use of the new T(Z) surveillance factor, which no longer includes the steady state axial power shape in the denominator, relative to the original W(Z) factor.

(2) Correction factors have been defined for the new F_Q surveillance equations which correct the results for any remaining errors associated with the actual plant conditions where the surveillance is performed, which may differ from the predicted surveillance condition. These factors are the A_{XY}(Z) factors for RAOC plants and the A_Q(Z) factors for CAOC plants, which have been added to the respective equations used to perform the $F_Q^W(Z)$ surveillance (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661). Two methods have been presented for representing the A_{XY}(Z) and A_Q(Z) factors. This includes the very simple assumption of unity for the factors, and a rigorous calculation of the factors at the specific conditions of each surveillance.

(3) The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillances at part power conditions. This is done by moving the relative power term of the condition where the surveillance is performed out of the surveillance factors (i.e., T(Z) and W(Z)) and into the actual surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P). For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at the 50 percent RTP power level.

(4) Required Actions for cases where $F_Q^W(Z)$ exceeds the F_Q limit have been more rigorously defined and eliminate all reliance on "rules of thumb" that may not be strictly applicable in all situations. This is implemented through the possible application of new RAOC or CAOC operating spaces, or through the pre-defined

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limitations on power and AFD provided in the COLR, which are rigorously calculated using the standard NRC-approved analysis methods. These changes ensure that corrective actions taken in the rare circumstances when $F_Q^W(Z)$ exceeds the F_Q limit will be effective at restoring the necessary margin.

(5) The application of the burnup dependent penalty factor (R_j) to account for predicted decreases in the transient $F_Q^W(Z)$ margin during the next 31 EFPDs has been modified to apply to all surveillances, independent of the trends in measured $F_Q^C(Z)$ margin. This is implemented by incorporating R_j into the surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661) and eliminating the conditional application of the penalty factor in the TS surveillances. This improvement corrects cases where the measured trend in $F_Q^C(Z)$ margin from the previous 31 EFPDs may be increasing, but the trend in $F_Q^W(Z)$ margin is decreasing due to changes in the surveillance factor data.

(6) Requirements to perform SRs 3.2.1.1 and 3.2.1.2 have been clarified in cases where $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed the F_Q limit. In any case where one or both parameters exceed the limit, both surveillances are required to be performed by the TS's Required Action.

(7) The F_Q surveillance TSs have been revised to rely on $F_Q^C(Z)$ surveillances during the initial power ascension after a refueling to demonstrate that continued power ascension is justified. The first $F_Q^W(Z)$ surveillance is not specifically required to be performed until 24 hours after the plant reaches a power level greater than 75 percent RTP. This change recognizes the technical fact that the surveillance factors needed to perform an accurate $F_Q^W(Z)$ surveillance at very low THERMAL POWER levels are difficult to accurately calculate in advance of the surveillance, and that the most accurate $F_Q^W(Z)$ surveillances will be obtained from equilibrium conditions at greater than 75 percent RTP. The change is justified by the fact that the $F_Q^C(Z)$ surveillances confirm the core is behaving as predicted. The first $F_Q^W(Z)$ surveillance that is performed following a refueling justifies continued power ascension until the next applicable surveillance frequency requirement is satisfied.

4.0 TECHNICAL EVALUATION

4.1 IMPROVED F_Q SURVEILLANCE FORMULATION

The rationale for the improved surveillance formulation was discussed in Section 3.1 and the new approach to defining $F_Q^W(Z)$ was summarized therein. Equation (4) represents the new formulation for RAOC plants and Equation (7) for CAOC plants. The derivation of these formulas in WCAP-17661 has been reviewed and found to be rigorous. In the following each of the important factors in Equation (4) for RAOC plants are considered. The evaluation for CAOC plants follows along similar lines.

The T(Z) factor is obtained as it always has been for the equivalent W(Z) {

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}.

The TR introduces the $A_{XY}(Z)$ and $A_Q(Z)$ factors defined in Equations (6) and (8), respectively, to adjust for a change in radial peaking factor due to difference in power level and control rod insertion relative to the reference core condition. In practice, the $A_{XY}(Z)$ and $A_Q(Z)$ factors allow for a slight adjustment, usually a reduction, in the calculated $F_Q^W(Z)$, when the $F_Q^W(Z)$ surveillance is conducted { }.
This factor is evaluated in detail in Section 4.1.1 of this SE.

The use of the measured $F_{XY}(Z)$ rather than $F_Q(Z)$ is an important part of the new RAOC formalism. Examples of measurements from different reactors are shown in WCAP-17661 and although measurement of $F_{XY}(Z)$ can be problematic in planes where grids reside, this is not an issue, because grid plane regions are excluded from surveillance as noted below. Section 4.4 of WCAP-17661 notes that the regions where there are measurement exclusions continue to be:

- Lower core region, generally[6] from 0 percent to 15 percent inclusive
- Upper core region, generally[7] from 85 percent to 100 percent inclusive
- Grid plane regions, ±2 percent inclusive
- Core plane regions, within ±2 percent of the bank demand position of the control banks

The use of the uncertainty factor U_F to account for both measurement and fuel manufacturing uncertainties was questioned (RAI No. 4) as it was not clear why a manufacturing uncertainty was needed. The RAI also questioned how the uncertainty in T(Z) was taken into account. The response to the RAI explains that the uncertainties used are conservative. The manufacturing (or engineering) uncertainty was originally introduced because the "measured" $F_Q(Z)$ in the formulation is a pin (i.e., fuel rod) power whereas the actual measurement is a fuel assembly power. The fuel manufacturing uncertainty is needed to account for pin-to-assembly factors[7] that compensate for this difference. Since the measurement already accounts for actual, as-manufactured conditions, this is not important. Furthermore, since the definition of the T(Z) factor is based on bounding calculations, it is not necessary to introduce additional uncertainty for this factor. Hence, it is concluded that the approach to uncertainty in the improved methodology is sufficiently conservative.

The last factor in Equation (4) is a penalty that is related to the elimination of the NOTE for SR 3.2.1.2. The NOTE (see also Section 4.4) required certain actions take place when the maximum over Z of $F_Q^C(Z)/K(Z)$[8] increased relative to the previous surveillance. The concern at the introduction of this requirement was deviations between measured and predicted steady state power shapes due to integral fuel burnable absorber-induced power shift (also known as axial offset deviation, AOD) or crud induced power shift (CIPS) both of which occur slowly over

[6] Per Footnote 4 on Page 3, the plant- or cycle-specific exclusion regions may be different.
[7] As noted in the RAI response, these pin-to-assembly factors account for the fact that the analytically derived pin factors are based on nominal design characteristics such as pellet enrichment, density, and burnable absorber loading. The engineering uncertainty addresses the effects of variations in the as-built fuel pellet from such nominal values.
[8] K(Z) is a function that defines the axial dependence of the acceptable value of F_Q.

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time. WCAP-17661 explains how AOD has been resolved so that fewer cores now experience it and the instances of AOD are less severe.

CIPS is explained in the report and in the response to RAI No. 6. Like AOD, it is less of a problem than it once was. "Furthermore, CIPS develops slowly and has a characteristic [delta axial offset] signature making it relatively easy to detect." Hence, the TR indicates that, should CIPS occur, the effect on transient F_Q margin can be addressed in a timely fashion (with modifications to core models) and there is no need for the generic penalty as expressed in the NOTE for SR 3.2.1.2. There are several reasons as to why this approach is reasonable and this review concurs with that reasoning.

The penalty that is proposed to be added (R_j) addresses downward trends in the F_Q margin that might be possible, due not to anomalies like CIPS, but rather to ordinary changes caused by cycle depletion. Essentially the penalty added at the surveillance point j is related to the ratio of the $F_Q^W(Z')$ expected at the next surveillance point in the cycle (i.e., point j+1) to the $F_Q^W(Z')$ at point j, where the prime indicates that it is at the elevation where the margin to the limit is smallest. This calculation is done prior to the start of the cycle and the R_j values are provided in the COLR. The minimum value that can be used is 1.0. This approach is reasonable and further justifies the elimination of the NOTE in SR 3.2.1.2.

CAOC plants will have the option of using Equation (7) to define the surveillance parameter. The major change is the introduction of the $A_Q(Z)$ factor. This factor is evaluated alongside $A_{XY}(Z)$ in Section 4.1.1.

4.1.1 Evaluation of A_{XY} and A_Q

WCAP-17661 proposes to implement, in the $F_Q^W(Z)$ surveillance formulation, new factors A_{XY} and A_Q for RAOC and CAOC W(Z) surveillances, respectively. These factors normalize the T(Z) and W(Z) functions for the RAOC and CAOC surveillances, respectively, to the power distribution conditions present at the time of surveillance. The present evaluation is written based on the PWROG response to RAI 15, which included proposed revisions to WCAP-17661. The introduction to RAI 15 provides a succinct explanation of the purpose and derivation of the A factors.

WCAP-17661, as revised, sets forth two methods for the A_{XY} and A_Q factors. Method 1 is to assume that it is always unity; in other words, surveillances would be performed without correcting for possible deviations from the reference condition, for which the T(Z) or W(Z) functions are determined. Method 2 is to perform on-line calculations.

Several considerations justify an allowance to keep the RAOC surveillance uncorrected. First among these is the fact that the vast majority of surveillances are performed in a Hot Full Power (HFP), All Rods Out configuration, such that there would be little deviation from the reference condition. Stated differently, in most cases, the A_{XY} factor would seldom deviate from unity, and deviations are usually expected to be minor. Second, the existing methodology does not include this correction. Third, in response to RAI 15.e, several tables were provided for a demonstration plant with several successive surveillances completed slightly above 80-percent RTP, with a 14-percent D-bank control rod insertion. These tables show that the A_{XY} factor removes a small amount of conservatism from the uncorrected surveillance, meaning that, in these conditions, a unity-value A_{XY} is conservative. The response to RAI 15.e included a table.

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illustrating what an A_{XY} correction would be if the plant were perturbed to a lower power level, close to 50-percent RTP, where the A_{XY} correction at the limiting margin elevation corrects an approximately { } of actual F_Q margin. The data provides an indication that the A_{XY} correction is usually minor, and that it increases in magnitude as the core begins to deviate more from the reference condition. Based on the demonstration that the A_{XY} factor is generally a minor correction to the $F_Q^W(Z)$ RAOC surveillance, the NRC staff determined that Method 1 for determining A_{XY} is an acceptable way to correct for surveillance conditions that are different than the reference conditions.

If the A_{XY} or A_Q factor is implemented using Method 2, it will be calculated using the methods listed in the response to RAI 15.c, and subject to the constraints discussed in the response to RAIs 15.b and 15.d. The response to 15.b includes references to the currently acceptable TRs describing methods for calculating the A_{XY} and A_Q factors. Additional, newer methods may also be used, provided they are specifically found to be acceptable by the NRC staff for doing so.

A_{XY} is, by definition, a ratio of {

} As such, the response to RAI 15.b describes several items that may cause discrepancies. The discrepancies arise because the T(Z) function is based on the original core design, whereas the A_{XY} numerator will reflect properties of the actual core, such as the actual inventory of reconstituted fuel assemblies and the use of an actual previous cycle shutdown burnup instead of the burnup window used in the original design. The response to RAI 15.b also indicates that the same discrepancies would be included in the A_{XY} denominator, or the $F_{XY}(Z)$ function for the surveillance condition, meaning that the ratio remains valid despite the difference between the as-designed and as-operated conditions. In addition, the response to RAI 15.b states that the depletion calculations for the as-operated conditions would be performed in the same manner as the original nuclear design model. These considerations ensure that the A_{XY} factor is a valid proportion to use when scaling the T(Z) function to correct for the surveillance conditions. Limitation 1 in Chapter 5 of this SE addresses requirements to use NRC-approved core design or surveillance methods to calculate the A_{XY}, and to perform the calculations consistent with the original core design model.

In large part, the A_Q factor is used in the CAOC – W(Z) surveillance the same as A_{XY} is used in RAOC surveillance, with a noteworthy difference. The A_Q factor was more likely to be greater than unity by a significant amount, particularly at rodded core elevations. Therefore, in the response to RAI 15.a, two additional constraints were placed on the use of a unity value A_Q, i.e., Method 1, to correct surveillance conditions that are different from the reference condition: such surveillance is precluded if the current axial offset is more than ±1.5-percent difference than the target value, or if Control Bank D is inserted to the elevation of anticipated limiting $F_Q^W(Z)$ margin. Subject to this constraint, which is also reflected in Limitation 1 in Chapter 5 of this SE,

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the NRC staff determined that the use of Methods 1 and 2 to calculate the A_Q factor for CAOC-W(Z) surveillance is acceptable, as the constraints will ensure that an explicitly calculated A_Q factor will be used when off-reference conditions would result in an $F_Q^W(z)$ surveillance that is unlikely to be sufficiently conservative.[9]

4.1.2 Conclusion Regarding Improved Surveillance Formulation

In summary, the new approach for the surveillance parameter $F_Q^W(Z)$ for both RAOC and CAOC plants is valid and eliminates a non-conservatism in the previous approach for RAOC plants. Thus, the revised $F_Q^W(Z)$ surveillance provides improved assurance that an implementing facility will be operated within the initial conditions assumed in the safety analyses, consistent with the requirements set forth in 10 CFR 50.36(c)(3). It is therefore acceptable as part of the surveillance methodology.

4.2 REVISIONS TO REQUIREMENTS UNDER CONDITION A OF TS 3.2.1B AND 3.2.1C

This change[10] proposes to revise the setpoint reductions that are required when $F_Q^C(Z)$ is not within limits. Specifically, Required Actions A.2 and A.3 will be revised replacing "1 percent for each 1 percent $F_Q^C(Z)$ exceeds limits" with "1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."

The proposed new wording will require a greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(Z)$ exceeds its limits. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, thermal power will be limited to ≤ 74 percent RTP. This new wording will require setpoint reductions of ≥ 26 percent, since this is the amount by which the thermal power is limited below the RTP. In other words, both the Neutron Flux – High trip setpoints and Overpower ΔT trip setpoints will require setpoint reductions of ≥ 26 percent. This is different from the current wording which requires a setpoint reduction of ≥ 1 percent.

The current wording implicitly assumed that the surveillance is always performed at full power. The revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance and appropriately defines the setpoint reductions.

The proposed revision to the Required Actions A.2 and A.3 addresses a potential issue with the actions for surveillance conducted at part-power. These changes will require an appropriate conservative reduction of the setpoints assuring that the limits on $F_Q^C(Z)$ assumed in the accident analyses remain valid. With the change, the requirements are appropriately worded for implementation since they are associated with the power level reductions defined in Required Action A.1.

[9] Note that Method 1 is appropriate and applicable when surveillance-specific W(Z) functions are created and included in a COLR revision prior to completion of a surveillance in conditions that are different from the previous reference condition, since the surveillance-specific W(Z) function effectively replaces the previous reference condition with those expected for the surveillance, meaning A_Q would be very close to unity.

[10] See Table 2 for a list of all changes.

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The NOTE to Condition A is revised. It previously stated that "Required Action A.4 shall be completed whenever this Condition is entered." This NOTE was considered to be confusing, given the changes being proposed for SR 3.2.1.1 and 3.2.1.2. The revised NOTE states: "Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling." This revision makes the NOTE consistent with the changes in the Required Actions and SRs, and it resolves the issue described above by making the NOTE more explicit.

These changes are not expected to cause any new accident or increase the likelihood of considered accidents. Rather, the changes are expected to reduce the consequence of accidents by assuring that $F_Q^C(Z)$ remains within the bounds assumed in the accident analyses. The proposed remedial actions are conservative compared to the current actions and can contribute to an improved margin of safety. Based on these considerations, the NRC staff determined that the proposed revisions are acceptable, insofar as they are consistent with the requirements established in 10 CFR 50.36(c)(2) for remedial actions, which may be established for conditions when an LCO is not met.

4.3 REVISIONS TO REQUIREMENTS UNDER CONDITION B OF TS 3.2.1B AND 3.2.1C

The newly added Required Actions replace prior actions requiring reduction of the AFD limits by one percent for each percent that $F_Q^W(Z)$ exceeded its limits, followed by a requirement to reduce the thermal power level if the former Required Action does not restore adequate $F_Q^W(Z)$ margin. Administratively, licensees do not implement the AFD Required Action and are presently required to reduce power if $F_Q^W(Z)$ exceeds its limits, in response to NSAL 09-5.

The revisions to the Required Actions associated with $F_Q^W(Z)$ exceeding its limits address the concern that the AFD reductions currently prescribed by TS are not sufficiently conservative to restore adequate margin to the heat flux hot channel factor. The existing TS Required Actions are based on assumptions that (1) the $F_Q^W(Z)$ violation occurs when the axial peak is outside the core mid-plane, and (2) constraining the power peaking in the core to its axial mid-plane region will restore the necessary margin. The TR notes that $F_Q^W(Z)$ violations are uncommon, and that when they occur, they do so more frequently outside the core mid-plane. However, the existing Required Action does not restore margin if the $F_Q^W(Z)$ violation occurs near the core mid-plane. To resolve the issue, the TR introduces a ROS or COS, depending on the power maneuvering control strategy, that can constrain AFD limits as before, but also introduces new T(Z) functions and possibly control rod insertion limits to further constrain maneuvering capability and restore the necessary margin. Rather than being based on assumptions that constraining the AFD limits yields the necessary margin, the new operating spaces are based on RAOC or CAOC analysis methodologies that have been approved for use by the NRC staff.

4.3.1 Required Actions B.1.1 and B.1.2; Deletion of NOTE Requiring SRs 3.2.1.1 and 3.2.1.2 Whenever Condition B is Entered

A new Required Action B.1.1 was included, which requires licensees to "Implement an RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits" whenever $F_Q^W(Z)$ is determined to be not within the limits. Based on the NRC staff review, PWROG also proposed to add the associated Required Action B.1.2, for instances in which the implementation of a new operating space requires control rod motion. It states "Perform

SR 3.2.1.1 and SR 3.2.1.2 [verification, respectively, that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits] if control rod motion is required to comply with the new operating space."

An ROS or COS is a unique combination of AFD limits and control bank insertion limits. The operating spaces are pre-analyzed using the approved methodology and included in the COLR. The number of operating spaces that will be included in the COLR will be determined by the utility in conjunction with the core designer. WCAP-17661 presents example calculations providing the thermal power limit and the required margin reductions for different $F_Q^W(Z)$ margin improvements for a RAOC plant (Table 6-10 for ROS) and thermal power limits for different $F_Q^W(Z)$ margin improvements for a CAOC plant (Table 9-7 for COS). For the RAOC plants, in the improved methodology the margin improvement can be confirmed using the T(Z) factors. Previously, it was presumed that the AFD limits would provide the necessary margin improvement.

As documented in the submitted TR, PWROG proposed to delete the NOTE in Condition B, which required the performance of SR 3.2.1.1 and SR 3.2.1.2 whenever the Condition was entered. This NOTE required verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. The deletion of this NOTE was the subject of Topics (a) and (c) under RAI 5, which sought to address the following issues:

- The use of a different operating space to gain margin improvement was considered an appropriate application of the new methodology presented. However, the NRC staff determined that situations may occur where a different rod insertion limit may result in control rod movement. Withdrawal of a control rod could potentially increase the $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values (RAI 5a).

- Inclusion of the requirements to perform SR 3.2.1.1 and SR 3.2.1.2 may be necessary to assure that the changes in $F_Q^C(Z)$ and $F_Q^W(Z)$ remain acceptable assuring that the margin is being maintained (RAI 5c).

The response to RAI 5 included modifications to the proposed Required Actions for Condition B of TS 3.2.1B and 3.2.1.C. Specifically, to address the above issues, Required Action B.1.2, with a Completion Time of 72 hours, was added. This new Required Action will require the completion of SRs 3.2.1.1 and 3.2.1.2 in the event that implementation of a new operating space results in the need to move the control rods to comply with a new rod insertion limit.

Completion of Required Action B.1, as originally proposed, may have resulted in a need to move the control rods. The measured $F_{xy}(Z)$ peak can occur adjacent to or in an assembly containing an inserted control rod and the withdrawal of the control rod could potentially increase the resulting $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values. Also, a revision to the allowed AFD band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion in order to obtain and maintain the AFD within the allowed operating band.

With the addition of Required Action B.1.2 (the current Required Action B.1 becomes B.1.1) to perform SR 3.2.1.1 and 3.2.1.2 will provide assurance that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits or appropriate actions are taken. Performing these surveillances will also provide the operators assurance that the margin is being maintained. A 72-hour Completion Time is provided to

ensure that the plant has time to restore equilibrium conditions in the event that control rod motions result in transient conditions.

In Topic (b) of RAI 5, the NRC staff determined that, to remain in the operating space defined by Required Action B.1, the operators would need to have a clear understanding that the margin improvement is being maintained. Additional information for the operator may be needed to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary. The NRC staff requested justification as to why a tabular presentation of the margin improvement as a function of the axial position or some other scheme in the COLR would not be required.

The response to RAI 5(b) stated that the margin can be determined by applying the new surveillance factors associated with the revised operating space to the power distribution measurement. Additionally, the response noted that $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances would now be required in the event that implementation of a new operating space requires control rod motion. Thus, performance of the SRs would provide the necessary margin confirmation. The NRC staff agrees with the response, since the concern was related to the implementation of new operating spaces in conjunction with control rod motion, which would require the performance of SRs 3.2.1.1 and 3.2.1.2.

Topic (d) of RAI 5 addresses the actions that will be taken by the operators to remedy potential violations of the newly implemented operating space associated with Required Action B.1. The response identified other TS Required Actions and SRs that would apply in such a situation, particularly with regard to control rod insertion limits and position. Because the potential for violation of the core operating limit parameters for an operating space can be addressed through existing TS Required Actions and SRs, the NRC staff determined that the response addressed the concern indicated in RAI 5d acceptably.

The improved methodology allows for the use of new operating spaces, as defined in the COLR. The addition of Required Action B.1.2 assures that for situations involving control rod movement SRs 3.2.1.1 and 3.2.1.2 will be performed to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits. Based on the review described above, the NRC staff determined that the proposed Required Actions B.1 are acceptable.

4.3.2 Required Action B.2 and Limitation on Thermal Power

The improved TSs define a new Required Action B.2 which includes four actions (B.2.1, B.2.2, B.2.3, and B.2.4). If the RAOC or CAOC operating spaces defined in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Actions B.2 are entered. The actions involve reducing the thermal power to less than the thermal power specified in the COLR along with reduction of the setpoints. For more explicit presentation of the changes and associated justifications, see Table 2.

The issues addressed in the review of these changes related to the change of the thermal power level. As noted in WCAP-17661-P, the reductions in the thermal power levels evaluated and included in the COLR. If the required margin improvement exceeds the level of pre-analyzed thermal power limits, then the option is to limit the thermal power to < 50 percent RTP. The 50 percent RTP applies to all Westinghouse plants that implement this TR and no plant-specific evaluations are involved. However, the response to RAI 7 stated that the 50 percent value is consistent with the required power reduction associated with other

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power distribution surveillances (e.g., $F^N_{\Delta H}$), and agreed to add paragraphs addressing this scenario in the BASES.

The need to limit thermal power to < 50 percent RTP is expected to be a rare occurrence. However, such a situation may indicate a core anomaly and is a useful discussion in the TS BASES for understanding of the operating personnel. Since the 50 percent value is consistent with the power reduction associated with other peaking factor surveillances the NRC staff finds the proposed Required Action B.2 acceptable for the purposes of this TR.

The final required THERMAL POWER limit provided in the COLR, supporting Required Actions B.2 for each ROS or COS, must be < 50 percent RTP. Even though the final power reduction amount is fixed, it is appropriate for inclusion in the COLR and not the TS, because the required amount of margin improvement at which this power reduction becomes necessary may vary from cycle to cycle. This is a limitation on the NRC staff approval of the TR, as discussed in Section 5.2 of this SE.

4.4 REMOVAL OF NOTES FOR F_Q SURVEILLANCE

Two Notes in the SRs are proposed to be deleted. The first Note, applied to both SR 3.2.1.1 and 3.2.1.2, required obtaining the power distribution map for measuring $F_Q^C(Z)$ and $F_Q^W(Z)$ in equilibrium conditions during power escalation at the beginning of each cycle[11]. The second NOTE applies to SR 3.2.1.2 and requires multiplication of $F_Q^W(Z)$ by a factor and increased surveillance under certain conditions.

The first NOTE has been a source of confusion and was interpreted differently by various utilities. From section 3.2.4 of the TR it appears that it was understood that a determination of $F_Q^C(Z)$ had to be obtained prior to exceeding 75 percent RTP. It is also considered that equilibrium conditions are not necessary for obtaining the power distribution map. The removal of the first NOTE removes any requirement for obtaining equilibrium conditions during the first power distribution map measuring $F_Q^C(Z)$. $F_Q^C(Z)$ is required to be verified after each refueling prior to exceeding 75 percent RTP in the first part of the Frequency.

In consideration of the removal of the first NOTE, the first Frequency for SR 3.2.1.1 no longer includes a definition of the applicable plant condition. However, *equilibrium conditions* are defined for other surveillances. Given that *equilibrium conditions* are defined for the conduct of surveillance, the NRC staff determined that a definition of *equilibrium condition* should be retained in the BASES discussion. The proposed change to the Bases associated with the SRs, to remove the definition of the *equilibrium condition*, can lead to confusion in implementing the surveillance and using the surveillance results. The response to RAI 9 proposed to define *equilibrium conditions*, for the purposes of SRs 3.2.1.1 and 3.2.1.2, as "...achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance." This definition was added to the BASES for both SRs. Based on this definition, and on its inclusion in the BASES, the NRC staff determined that the disposition regarding the plant condition for these surveillances was acceptable.

[11] The first Note stated, "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which [*sic*] a power distribution map is obtained."

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The effect of the removal of the first NOTE on SR 3.2.1.2 is that $F_Q^W(Z)$ will not be required to be determined until 24 hours after exceeding 75 percent RTP, instead of before exceeding 75 percent RTP following a refueling outage as currently specified.[12] For further detail regarding the change to the time the first $F_Q^W(Z)$ surveillance is required, refer to Item 7 in Section 3.3, and to Section 4.7, of this SE.

The second NOTE defined the penalty factor for $F_Q^W(Z)$. In the improved methodology, the penalty factor is embedded in the methodology and a separate penalty factor is not applicable. In addition, it is understood that an increasing trend in $F_Q^W(Z)$ measurement is not indicative of future margin trends and accordingly, increased surveillance based on an increasing trend may not be desired. Additional review considerations regarding the deletion of this NOTE appear in Section 4.6 of this SE.

Based on the considerations discussed above, the NRC staff determined that the proposed deletion of the NOTEs associated with F_Q surveillance was acceptable. In summary, the deletion of the first note will eliminate confusion and inconsistency among implementing licensees, the *equilibrium condition* required for the surveillances will be defined in the BASES, and the penalty factor associated with the second NOTE is now embedded in the methodology. The NRC staff also notes that revisions made to the NOTES in Condition A and Required Action B.2 clarify some of the conditions under which SRs 3.2.1.1 and 3.2.1.2 are necessary, further obviating the need for these NOTES.

4.5 <u>REVISION OF SECOND SURVEILLANCE FREQUENCY FOR SRS 3.2.1.1 AND 3.2.1.2</u>

Verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits (SR 3.2.1.1 and SR 3.2.1.2) includes a second requirement in the Frequency column of "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." This requirement assures verification of the F_Q limits whenever a significant increase of thermal power level has occurred.

The increase in the time interval for completing the required surveillance from 12 to 24 hours was based on the argument that some plant TSs have used the 24-hour time interval without any adverse effects and there is an extremely small likelihood of limiting power shapes or limiting design basis events occurring during this period.

Additional justification provided in Reference 7 noted that $F_Q^C(Z)$ and $F_Q^W(Z)$ will already have been measured at least once at reduced power conditions, and these measurements provide assurance that increasing power to another, higher thermal power plateau will not result in the exceedance of F_Q limit prior to the completion of the next surveillance.[13] The NRC staff agrees that, given the constraints that (1) $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances have been completed at a lower power level, (2) the next power level does not exceed the power level at which the $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances were completed by more than ten percent, and (3) the surveillances

[12] The modification to the SR, requiring its performance within 24 hours after exceeding 75-percent RTP, was provided in Reference 7.

[13] The response to RAI 8 included similar justification, but also referred to Westinghouse Fuel Conditioning Guidelines. Adherence to such guidelines is not a requirement, and hence was not considered by the NRC staff.

are repeated within 24 hours (instead of 12) of achieving the higher thermal power plateau, the risk of exceeding the F_Q limit is acceptably minimized. Such constraints are reflected in the TS, as revised in Reference 7.

Based on these considerations identified in Reference 7, the NRC staff determined changing the second surveillance time from 12 hours to 24 hours is acceptable. A discussion of the reasons for allowing 24 hours to complete F_Q surveillance is included in the BASES.

4.6 DELETION OF NOTE IN SR 3.2.1.2

The NOTE in SR 3.2.1.2 required increasing the Frequency to once per 7 EFPD for certain conditions until these conditions are satisfied. The intent of the NOTE in the current TS is to account for potential increases in $F_Q^W(Z)$ between surveillances. It required application of the greater of a 1.02 factor or a factor specified in the COLR whenever the measurement indicated that the maximum value of $F_Q^C(Z)$/K(Z) has increased. Alternatively, SR 3.2.1.2, "Verify that $F_Q^W(z)$ is within limit," is repeated once per 7 EFPD until $F_Q^W(Z)$ is within limit with the penalty factor applied or two successive flux maps indicate that $F_Q^C(Z)$/K(Z) has not increased.

The justification for eliminating the NOTE is that the required penalty factor is part of the $F_Q^W(Z)$ formulation in the new methodology. A penalty factor R_j is introduced and will be included in the COLR. The magnitude of the penalty factor is calculated based on the predicted margin trends and no additional assumptions or considerations are necessary.

The use of the new methodology and the built-in penalty factor has a number of advantages: (a) it will better capture the expected trend in the margin avoiding any lag in the application as was the case previously, (b) it avoids application of an arbitrary 2-percent minimum penalty, and (c) it eliminates the need for more frequent surveillance.

The issue addressed in this change is that past measurement trends are no longer being used (RAI 6b). This is justified because, as stated in WCAP-17661, past measurement trends of $F_Q^C(Z)$/K(Z) may or may not be indicative of future margin trends.

The response to RAI 6 provided the following additional information:

- In some situations, measured trends in $F_Q^C(Z)$ may not always be indicative of the same margin trends in the measured $F_Q^W(Z)$. An example of such a situation is when the axial power distribution of the core is in transition from a cosine shape to a flattened saddle shape.

- During the initial onset of CIPS, a similar decreasing trend for both $F_Q^C(Z)$ and $F_Q^W(Z)$ may not necessarily occur. An increasing trend in the margin of $F_Q^C(Z)$ may occur due to a decrease in the radial peaking ($F_{XY}(Z)$) in the affected elevation of the highest power assemblies due to preferential accumulation of boron-containing crud there and the AFD being closer to zero or slightly negative for onset of CIPS. The trend in $F_Q^W(Z)$ is driven largely by the T(Z) or W(Z) surveillance factors.

Based on its review of the additional information provided in the response to RAI 6, the NRC staff determined that (1) it is an improvement that past measurement of $F_Q^C(Z)$ will no longer be used and (2) the NOTE in SR 3.2.1.2 for more frequent surveillance based on past measurements of $F_Q^C(Z)$ should no longer be required. The use of the penalty factor in the methodology to determine $F_Q^W(Z)$ is appropriate in assuring that this parameter is within limits. Thus, the NRC staff determined that the deletion of the NOTE, combined with the inclusion of a penalty factor in the $F_Q^W(Z)$ surveillance formulation is acceptable. The surveillance provides an acceptable confirmation that the power distribution remains within analyzed limits, including in instances where the surveillance indicates trends of reducing margin to $F_Q^W(Z)$ limits.

4.7 CHANGE IN FREQUENCY OF SR 3.2.1.2 DURING POWER ESCALATION

The current SRs for $F_Q^W(Z)$ (SR 3.2.1.2) are the same for both the CAOC and RAOC versions of the current F_Q Surveillance. The first part of the three-part surveillance frequency required assuring $F_Q^W(Z)$ within limits "once after each refueling prior to THERMAL POWER exceeding 75% RTP." This requirement is being changed to state that $F_Q^W(Z)$ must be verified to be within the limits following each refueling within 24 hours after THERMAL POWER exceeds 75 percent RTP.

The intent of this SR is to ensure that the F_Q will be maintained during future non-equilibrium operation within the allowed operating space.

The surveillance factors needed to perform an accurate $F_Q^W(Z)$ margin assessment at a very low power are difficult to generate without the advance knowledge of the expected operating power profile during the power ascension. The improved methodology presented in the TR mitigates this concern. Performing the surveillance after exceeding 75 percent power ensures that surveillance will be conducted with appropriate steady state peaking factors measured at or near the peak power level and core conditions where future non-equilibrium conditions have the potential for challenging the fuel limits.

In this approach, power ascension within acceptable power peaking limits is assured, based on $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances. The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillance at reduced power conditions. For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at 50 percent RTP power level. In addition, as noted in the TR, core power distribution measurements and physics testing performed at low powers (<50 percent RTP) confirm that the core is loaded properly and is operating consistent with expectations.

Based on the considerations discussed above, the NRC staff determined that the technical justification for changing the first frequency of SR 3.2.1.2 is acceptable. Primarily, the revised Frequency assures that the initial $F_Q^W(Z)$ surveillance is performed within 24 hours after exceeding 75 percent RTP. Further, the ability to perform an accurate $F_Q^W(Z)$ margin assessment is substantially improved once steady-state operation above 75-percent RTP is achieved.

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4.8 CHANGES TO BASES

For the changes to the RAOC and CAOC F_Q TSs (TS 3.2.1B and TS 3.2.1C), corresponding changes were made to the TS BASES. WCAP-17661-P provides the changes to the BASES to make them compatible with the changes made to the TSs. The changes to the BASES were reviewed and were discussed as part of the RAIs. The conclusion of the review was that additional discussions or clarifications for some aspects would be beneficial and provide improved clarity and understanding of the requirements in the TSs.

Additional discussions in the following areas were added in the BASES as part of the review of WCAP-17661:

1. Under the change for both RAOC and CAOC plants, Required Actions are now different for Conditions A, $F_Q^C(Z)$ not within limit, and B, $F_Q^W(Z)$ not within limit. When $F_Q^C(Z)$ is not within limit, reduction of THERMAL POWER is required along with reduction of setpoints and performance of SR 3.2.1.1 and SR 3.2.1.2. Whereas, when $F_Q^W(Z)$ is not within limits, two alternative actions may be applicable as discussed in the response to RAI 1. The first alternative action is included in Required Action B.1.1. This Required Action first requires implementation of a different operating space. If an appropriate operating space cannot be implemented, then a reduction of THERMAL POWER and setpoints and performance of SR 3.2.1.1 and SR 3.2.1.1 are required as an alternative. These aspects are discussed in the "Actions" section of the Bases.

   The changes to the Condition B Required Actions, when $F_Q^W(Z)$ exceeds limits are intended to avoid THERMAL POWER reduction through implementation of a different operating space (Required Action B.1). However, when both $F_Q^C(Z)$ and $F_Q^W(Z)$ are not within limits, Required Action for $F_Q^C(Z)$ will require a reduction of THERMAL POWER. The corresponding evaluation and action for $F_Q^W(Z)$ may be different. For example, Condition A ($F_Q^C(Z)$ not within limit) requires a reduction of THERMAL POWER ≥ 1 percent for each 1 percent $F_Q^C(z)$ exceeds limit, but Condition B ($F_Q^W(Z)$ not within limit) may require a reduction of THERMAL POWER as evaluated and set forth in the COLR.[14] As explained as part of the response to RAI 1, if both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, Required Action A.1 will be completed first due to the 15-minute Completion Time. Once the power level is reduced below that specified by Required Action A.1, the current operating peak power density will be restored to less than the value assumed in the safety analysis. As noted in the response to RAI 1, this Required Action may not ensure that the $F_Q^W(Z)$ limit is met.

   The new Required Actions for Condition B are proposed to either implement a new operating space or a reduction in THERMAL POWER, and are required in order to ensure compliance with the $F_Q^W(Z)$ limit during future operation under transient conditions.

[14] While Tables 6-10, 9-7, C-7, and F-7 in the TR show examples where the margin was defined in 5 percent decrements, the NRC staff understands that other decrements may be used, provided such decrements are analytically supported.

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As a follow-up to the RAIs, these aspects are discussed and the BASES, which contain the clarifications regarding implementation of the proposed changes under different scenarios of $F_Q^C(Z)$ and $F_Q^W(Z)$ violations.

2. Under the proposed change, the new Required Action B.1.1 requires implementation of a RAOC/CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ within its limits. If control rod motion is needed as a result of entering Condition B and performing Required Action B.1.1, the fundamental measured power distribution will change as a result. As stated in the response to RAI 5, in some cases, a revision to the allowed AFD band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion, in order to obtain and maintain the AFD within the allowed operating band. If the implementation of Required Action B.1.1 results in a need to move control rods, SR 3.2.1.1 and SR 3.2.1.2 should be performed to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. This is addressed through the addition of Required Action B.1.2 and associated discussions are included in the Bases.

3. Under the proposed changes, if the operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then THERMAL POWER must be reduced to less than the thermal power specified in the COLR. Also, AFD limits must be reduced by the amount specified in the COLR. If the required margin improvement exceeds the level of any pre-analyzed thermal power limits, the COLR will specify that the thermal power is limited to <50 percent RTP.

   The requirement to reduce thermal power to <50 percent RTP is discussed in the BASES as part of the review of the submittal to ensure completeness of the actions required and to provide clear guidance to the plant operators.

4.9 <u>INTERFACES WITH OTHER REQUIREMENTS</u>

In assessing the changes to TS 3.2.1B and TS 3.2.1C, the interface of these requirements with other TS requirements was reviewed. The intent was to determine whether changes in these requirements may necessitate changes in other requirements.

Based on the review, two interfacing aspects were identified:

1. It was noted that TS 3.2.1A, Heat flux Hot Channel Factor ($F_Q(Z)$ (CAOC – F_{xy} Methodology)) is included for some plants. But, the concepts used in TS 3.2.1C are not used for TS 3.2.1A, i.e., TS 3.2.1A is not modified to use a different operating space and avoid reduction in THERMAL POWER. This issue was the topic of RAI 11.

2. TS 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," which provides limits and associated SRs for QPTR, may be affected by the proposed changes. The QPTR limits ensure that the nuclear enthalpy rise hot channel factor ($F_{\Delta H}^N$) and $F_Q(Z)$ remain below their limiting values by preventing an undetected change in the gross radial power distribution. The QPTR limit of 1.02, at which corrective action is required, provides a margin of protection for both the departure from nucleate boiling ratio and linear heat generation rate contributing to excessive power peaks resulting from X-Y plane power tilts. Assurance is needed that the margin of protection is not being lost or that adequate margin of protection will still be maintained. This issue was the topic of RAI 12.

The response to RAIs 11 and 12 provided the following clarifying information:

1. The Required Actions in TS 3.2.1A are more conservative than those in proposed TS 3.2.1C. This is because TS 3.2.1A effectively treats all cases where the $F_Q(Z)$ limit is exceeded as if the plant is currently operating with a peak power density in excess of what is assumed in the safety analysis. The plants that have implemented TS 3.2.1A do not have to implement proposed TS 3.2.1C, since the resulting surveillance required by TS 3.2.1A is valid and conservative.

2. The implementation of a different operating space in the event that the performance of an $F_Q^W(Z)$ surveillance determines that the F_Q limit is not met would not significantly affect the indicated QPTR on the excore detector, nor would it affect the actual in-core power distribution symmetry.

3. Addition of a Required Action of performing SR 3.2.1.1 and SR 3.2.1.2, with a Completion Time of 72 hours, when a new operating space is implemented, which results in control rod motion, will provide the requisite margin of protection. With this addition, the margin to safety analysis limits will be determined and confirmed after the implementation of a new operating space, including the effects of any existing QPTR. Once this is done, the same initial conditions are established with respect to the continued applicability of TS 3.2.4, as would otherwise have been present before the new operating space was implemented.

4.10 SUMMARY OF KEY REVIEW TOPICS

Based on the review described above, the NRC staff determined that the reformulated F_Q surveillance is acceptable. The following paragraphs reiterate the more significant of the NRC staff conclusions.

Regarding changes to the TS associated with $F_Q^C(Z)$, or the instantaneous heat flux hot channel factor, the NRC staff determined that the new Required Actions and Completion Times are more restrictive than the existing, and as such, concluded that they are acceptable.

Regarding the reformulation of the $F_Q^W(Z)$ surveillance, the NRC staff developed the following review considerations:

1. The use of a planar radial surveillance in conjunction with T(Z) factors eliminates axial sensitivities in the surveillance procedure, and eliminates the reliance on the current guidance to adjust W(Z) factors when performing $F_Q^W(Z)$ surveillance in conditions significantly different from those assumed in the RAOC or CAOC analysis. As noted in Section 4.1 of this SE, the surveillance formulation, i.e., treatment of uncertainties and power distribution perturbations over the surveillance interval, is otherwise equivalent to the existing.

2. The use of A_{XY} and A_Q, to correct the surveillance parameter for conditions other than the reference condition, as discussed in Sections 4.1 and 5.2 of this SE, is acceptable, provided the methodological description provided in response to RAI 15 is followed.

3. The incorporation of the R_j correction factor, which conservatively adjusts for downward trends in $F_Q^W(Z)$, directly into the surveillance supports the elimination of the NOTE associated with SR 3.2.1.2, as discussed in Sections 4.1 and 4.4 of this SE.

Based on the above considerations, the NRC staff concluded that the reformulated $F_Q^W(Z)$ surveillance was acceptable.

Finally, the NRC staff considered the revisions to the Required Actions associated with not meeting the $F_Q^W(Z)$ LCO, and determined that they are acceptable. The revision provides for successively more restrictive operating spaces, which help to ensure that the core operates with sufficient margin to ensure that the peak power remains within analyzed limits. Perhaps more importantly, the operating spaces and associated margin factors are now analytically based. This improvement provides assurance that completion of the Required Actions ($F_Q^W(Z)$ is not within its limits) would ensure that the core power distribution remains within the limits analyzed in the ECCS evaluation. If the more restrictive operating spaces fail to provide the requisite margin, similar reductions in rated thermal power level and reactor trip setpoints to those required for $F_Q^C(Z)$ become necessary.

In conclusion, the NRC staff review determined that the revisions to the heat flux hot channel factor TS were acceptable. The revisions provide a more robust means for performing the $F_Q^W(Z)$ surveillance, a series of more restrictive operating spaces if the $F_Q^W(Z)$ LCO is not met, and a more clearly defined set of SRs and Required Actions. The TS changes also provide reasonable assurance that a core operated in accordance with these TS will remain within the power distribution limits assumed in the facility safety analyses.

5.0 APPROVAL LIMITATIONS

The NRC staff review identified two limitations, adherence to which are necessary to ensure acceptable implementation of WCAP-17661.

5.1 LIMITATION 1: USE OF A_{XY} AND A_Q

As discussed in Section 4.1.1 of this SE, the use of Methods 1 and 2 are acceptable for calculating A_{XY} and A_Q when performing RAOC and CAOC W(Z) surveillances, subject to the following limitations:

1. The NRC-approved methods provided in the response to RAI 15.b must be used to perform the surveillance-specific A_{XY} or A_Q calculations. Newer methods with similar capabilities may be considered acceptable provided the NRC staff specifically approves them for calculating A_{XY} and A_Q factors.

2. The depletion calculation used to determine the numerator and denominator of the A_{XY} or A_Q factor must be performed similarly to the original design calculation, as described in the response to RAI 15.c.

3. The use of Method 1 for calculating A_Q is only acceptable subject to the constraints discussed in the response to RAI 15.a. The surveillance Axial Offset must be within 1.5-percent of the target AO, and there must be assurance that the limiting $F_Q^W(Z)$ location does not lie within a rodded elevation at the time of surveillance. Note that the use of Method 1 remains acceptable when surveillance-specific W(Z) functions are used.

5.2 LIMITATION 2: POWER LEVEL REDUCTION TO 50 PERCENT RTP

As noted in Section 4.3.2 of this SE, the use of 50 percent as the final power level reduction in the event of failed F_Q surveillance is not included in the TS, but rather in the BASES and in the COLR. As such, this final power level, 50 percent, must be implemented on a plant-specific basis and included in COLR input generated using this methodology, in order to use this TR.

6.0 CONCLUSIONS

Based on the review described in the preceding SE, and subject to the limitations provided in Chapter 5, the NRC staff has determined that the RAOC and CAOC surveillance formulations and required actions proposed in WCAP-17661 are acceptable. The TR may be considered approved for use by the NRC staff, for the purpose of justifying the TS changes contained therein.

7.0 REFERENCES

1. PWROG, "Improved RAOC and CAOC F_Q Surveillance Requirements," Reports WCAP-17661-P (Proprietary) and WCAP-17661-NP (Publicly Available); and Transmittal Letter OG-13-427, Project No. 694, January 2, 2014, ADAMS Package Accession No. ML14009A098.

2. U.S. NRC, "Standard Technical Specifications – Westinghouse Plants," NUREG-1431, Volume 1, Revision 4, "Specifications," and Volume 2, Revision 4, "Bases," April 2012, ADAMS Accession Nos. ML12100A222 (Volume 1) and ML12100A228 (Volume 2).

3. PWROG, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC RQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-16-273 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, September 13, 2016, ADAMS Package Accession No. ML16291A531.

4. PWROG, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-18-35 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, February 15, 2018, ADAMS Package Accession No. ML18053A269.

5. Westinghouse Electric Company, "Relaxed Axial Offset Control F_Q Technical Specification Actions," NSAL-09-5, Revision 1, September 23, 2009. This document was not formally transmitted to the NRC and it is not available in ADAMS.

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6. U.S. NRC, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," Generic Letter 1988-16, October 4, 1988, ADAMS Accession No. ML031200485.

7. PWROG, "Transmittal of the Response to the Revised Draft Safety Evaluation (DSE) for WCAP-17661-P/WCAP-17661-NP, Revision 1 (PA-LSC-0795)," Letter No. OG-18-188 and Enclosures 2-4 (Publicly Available) and Enclosures 1 and 5 (Proprietary), August 2, 2018, ADAMS Package Accession No. ML18318A351.

Attachments: Appendix
Comment Resolution Table

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Date: November 23, 2018

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APPENDIX: TABLES

TABLE 1: POWER DISTRIBUTION TERMS

1.A: Peaking Factors		
Term	**Name**	**Definition**
F_Q	Total Heat Flux Hot Channel Factor	The ratio of peak to average power density in the core
F_{XY}	Planar Radial Peaking Factor	The ratio of peak-to-average power density in a radial core plane

1.B: Limits, Functions, and Multipliers		
Term	**Name**	**Definition**
K(Z)	Axial shape function	Normalizes $F_Q(Z)$ as a function of core height. Included in COLR.
W(Z)	W(Z) function	Analytical ratios used in the current F_Q surveillance formulation to characterize the maximum expected increase in the surveillance *$F_Q(Z)$ x Power* relative to the non-equilibrium *$F_Q(Z)$ x Power.*
T(Z)	T(Z) function	Analytical ratios used in the improved F_Q surveillance formulation for RAOC plants to characterize the maximum transient P(Z)
CFQ	Rated thermal power (RTP) F_Q limit	Absolute limit applied to F_Q. Included in COLR. Term used in STS and STS Bases (Ref. 2).
P	Fraction of RTP	Used to scale the measured power distribution based on the core operating power level. Term used in STS and STS Bases (Ref. 2).
P_{rel}	Core average relative power	Same as fraction of RTP, above, but used in surveillance formulations presented in WCAP-17661.
P_{rel}^{SS}	Surveillance relative power	Actual power divided by the rated thermal power at the time of surveillance
P(Z)	Core average axial power shape	Planar average power at elevation Z, divided by volume average power of the core
$P(Z)_{ref}^{P}$	Relative axial power shape	Relative axial power predicted at the reference condition
PFXY	Power factor multiplier	Power factor multiplier for F_{XY}. Provided in the COLR.
A_{XY}	Correction factor for RAOC surveillance conditions	Used to adjust the $F_Q^W(Z)$ value in instances when the surveillance is conducted in a different condition, i.e., thermal power level and control rod insertion, than the reference condition (typically hot full power, all rods out, equilibrium xenon).
A_Q	Correction factor for CAOC surveillance conditions	Used to adjust the $F_Q^W(Z)$ value in instances when the surveillance is conducted in a different condition, i.e., thermal power level and control rod insertion, than the reference condition (typically hot full power, all rods out, equilibrium xenon).
R_j	Penalty factor	Used to account for reductions in F_Q margin that may occur for trends that follow burnup over the surveillance interval

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TABLE 1: POWER DISTRIBUTION TERMS (CONTINUED)

1.C: F_Q Terms		
Term	**Name**	**Definition**
$F_Q(Z)$	Heat flux hot channel factor	Maximum local heat flux on the surface of a fuel rod at core elevation Z, divided by the average fuel rod heat flux. In the WCAP-17661 methodology, this term is approximated by multiplying $F_{XY}(Z)$ by $P(Z)$.
$F_Q^M(Z)$	Measured heat flux hot channel factor	Measured value of $F_Q(Z)$ obtained directly from the flux map results.
$F_Q^C(Z)$	--	The measured value, $F_Q^M(Z)$, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
$F_Q^W(Z)$	Transient $F_Q(Z)$	The maximum $F_Q(Z)$ calculated to occur in normal operation over the next surveillance interval. Includes margin for (1) fuel manufacturing tolerances, (2) flux map measurement uncertainty, and (3) operational transients anticipated over the next surveillance interval. The product of $F_Q^C(Z)$ and $W(Z)$.
F_Q^{PR}	–	The predicted value of the Heat Flux Hot Channel Factor. A maximum value that includes load follow impacts.
F_Q^{RTP}	Rated thermal power F_Q limit	Same as CFQ.

1.D: F_{XY} Terms		
Term	**Name**	**Definition**
$F_{XY}(Z)$	Height-dependent radial peaking factor	Radial peaking factor, measured using the incore detector system, at a given plane of the core.
F_{XY}^M	–	The measured value of F_{XY} obtained directly from the flux map results.
F_{XY}^C	--	The measured value, F_{XY}^M, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
F_{XY}^{RTP}	–	The limit of F_{XY} at RTP.
F_{XY}^L	–	The limit of F_{XY} at the current thermal power level.

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TABLE 2: SUMMARY OF PROPOSED CHANGES

2.A: Title			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B, Title	$F_Q(Z)$(RAOC-W(Z) Methodology)	$F_Q(Z)$(RAOC-T(Z) Methodology)	Use of a different methodology requires the name change

2.B: Actions, Condition A			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B and 3.2.1C, Required Actions A.2 and A.3	"... 1% for each 1% $F_Q^C(Z)$ exceeds limit"	"... 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."	Revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance. The current wording is only appropriate if the surveillance is performed at full power. The new wording will require greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(z)$ exceeds its limit. (WCAP, Section 3.2.2, pg.3-12)
NOTE in Condition A	Required Action A.4 shall be completed whenever this Condition is entered.	Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.	Makes it consistent with other changes.

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TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.C: Actions, Condition B			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B and 3.2.1C, New Required Action B.1.1		B.1.1 states, "Implement a RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits."	Implementation of a New RAOC/CAOC operating space restores $F_Q^W(Z)$ within limits.
New Required Action B.1.2		B.1.2 states, "Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space."	When control rod motion is required, surveillance assures that $F_Q^W(Z)$ remains within limits.
TS 3.2.1B, Required Action B.2.1 (previously B.1)	Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER and reduce AFD limits as specified in the COLR.	Evaluations in the COLR will provide the applicable power level and AFD limits to assure $F_Q^W(Z)$ within limits.
TS 3.2.1C, Required Action B.2.1 (previously B.1)	Reduce THERMAL POWER ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER as specified in the COLR.	Core models provide basis for determining the axial location of the minimum margin in the actual core.
TS 3.2.1B, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"... 1% for each 1% that the maximum allowable power of the AFD limits is reduced"	"... 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	With the change, peak power densities will remain within limits of the safety analyses. Prior requirements may not ensure that non-equilibrium operation was bounded by the maximum power distribution assumptions in all circumstances.
TS 3.2.1C, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"... 1% for each 1% $F_Q^W(Z)$ exceeds limits"	"... 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	
TS 3.2.1B, Completion Time for Required Action B.2.4	"Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."	"Prior to increasing THERMAL POWER above the limit of Required Action B.2.1"	Proposed change in TS 3.2.1B will make it consistent with the Completion Time defined in TS 3.2.1C. Completion Time in TS 3.2.1C did not need any changes.
NOTE in Condition B	Applicable whenever Condition B is entered	Moved (with addition "prior to increasing THERMAL POWER above the limit of Required Action B.2.1") under Required Action B.2.1, i.e., applicable when Required Actions under B.2.1, B.2.2, B.2.3 and B.2.4 are entered.	Required Action option B.1 assumes that a RAOC operating space specified in the COLR satisfies $F_Q^C(Z)$ and $F_Q^W(Z)$ limits if no control rod (CR) motion is needed. Required Action B.1.2 requires surveillance CR motion is needed. Required Action B.2.4 institutes performance of the SRs if option B.2 is used.

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TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.D: Surveillance Requirements (SRs)			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
NOTE for SRs	NOTE states that "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."	The NOTE is deleted.	The NOTE has been a source of confusion and interpreted differently by various utilities. Existing frequencies, together, are unambiguous and appropriately verify $F_Q^C(Z)$ during the initial power escalation and throughout the operating cycle.
SR 3.2.1.1, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions ..."	"Once within [24] hours after achieving equilibrium conditions ..."	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.
NOTE for SR 3.2.1.2	The NOTE in SR 3.2.1.2 requiring increasing SR frequency considering an in-crease factor for $F_Q^W(Z)$ when increase from previous evaluation has been noted.	The NOTE is deleted.	The penalty factor in the improved methodology is based on predicted rather than measured trends in transient F_Q margin, and is applied when SR 3.2.1.2 is performed. It is argued that the past measurement trends are not indicative of future margin trends.
SR 3.2.1.2, 1st requirement in the Frequency column	"Once after each refueling prior to THERMAL POWER exceeding 75% RTP"	"Once after each refueling within [24] hours after THERMAL POWER exceeds 75% RTP."	Verification will still be performed within a reasonable time and prior to extended non-equilibrium operation at power levels where the maximum peak linear heat rate could potentially be challenged.
SR 3.2.1.2, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THEMAL POWER at which $F_Q^W(Z)$ was last verified."	"Once within [24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified."	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.

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WCAP–17661, "Improved RAOC and CAOC FQ Surveillance Technical Specifications"
Draft Safety Evaluation Comment Disposition

Page(s)	Line(s)	PWROG Comment	NRC Staff Discussion
2	20 – 26	The text "The non-conservatism becomes apparent…" [implies] that this paragraph is continuing to discuss the item discussed in the 2nd paragraph (i.e., the non-conservative Required Action identified in NSAL-09–5). However, the 3rd paragraph discusses a different issue (i.e., the sensitivity of RAOC Surveillance measurements to the conditions where the Surveillance is performed). Therefore, the first sentence should be revised to: "Another potential non–conservatism becomes apparent…."	Change accepted.
3	11	Footnote 3 is not consistent with Section 5.1, Limitation 1, and should be revised to be consistent with Section 5.1, Limitation 1. As written, Footnote 3 prohibits the use of $A_{XY}(Z)$ and $A_Q(Z)$ values less than 1.0.	Footnote 3 was deleted. Note that PWROG comment referred to Section 5.2, Limitation 2, which was renumbered as Limitation 1, and is now contained in Section 5.1 of the SE.
8	20	It is a "measurement" uncertainty, not an "instrument" uncertainty. Insert "fuel" before "manufacturing."	Changes accepted.
16 – 17		See comment on Page 3, Line 11.	Footnote 6 deleted.
19	8 – 9	The derivation of R_j is also rigorous.	Phrase, "…with the exception of the penalty factor R_j." deleted. Note that the NRC staff evaluates the rigor of the R_j factor as discussed in a later paragraph in SE Section 4.1.
19	38	See comment on Page 8, Line 20.	SE text edited for consistency with previous comment.
20	25	*…not to anomalies like CIPS, but rather to ordinary…*	Change accepted.
20	29 – 30	*…and the R_j values are ~~to be found~~ in the COLR…*	*…and the R_j values are provided ~~to be found~~ in the COLR…*
20	40 – 42	The previous sentence discusses both $A_{XY}(Z)$ and $A_Q(Z)$. Beginning this sentence with the words, "This factor is intended to normalize the T(Z) function…" is not clear, in particular since only T(Z) is mentioned in the second sentence. The 2nd sentence should be revised to "The $A_{XY}(Z)$ factor is intended to normalize the T(Z) function…"	The NRC staff intended for subject discussion to refer to both factors, and revised SE text accordingly.

Attachment

WCAP–17661, "Improved RAOC and CAOC FQ Surveillance Technical Specifications"
Draft Safety Evaluation Comment Disposition

21	1 – 4	This sentence discusses both the $A_{XY}(Z)$ and $A_Q(Z)$ functions, therefore, the end of the sentence should be revised to state "…for which the T(Z) or W(Z) functions are determined."	Change accepted.
21	6 – 24	Editorial changes throughout paragraph.	Changes accepted.
22	1 – 4	Editorial changes throughout paragraph.	Changes accepted.
22	9 – 15	Editorial changes throughout paragraph.	Changes accepted.
22	16 – 21	The response to RAI 15.a discussed the potential use of Method 1 for AQ (i.e., AQ(z)=1.0) if "surveillance specific" W(z) factors are provided for a specific core condition different from the normal reference surveillance condition for a CAOC plant (i.e., all rods out, 100% RTP). If a utility identifies in advance that they want to perform a Surveillance at a specific condition (for example 80% RTP, with D-Bank inserted 20% near the beginning of the cycle), W(z) factors can be generated specific to that surveillance condition using the NRC approved CAOC methodology and added to the COLR. This methodology would provide an accurate result without explicitly requiring the calculation of AQ(z) using Method 2. Currently, the Draft Safety Evaluation does not specifically discuss the potential use of Method 1 when surveillance specific W(z) factors are used. Method 2 AQ(z) calculations would be required to be performed for such a Surveillance. Therefore, a statement should be added to Sections 4.1.1 and 5.2.3 which specifically approves the use of Method 1 for AQ(z) when a surveillance is performed at conditions different from the normal reference condition using surveillance specific W(z) factors that are consistent with the	Although the NRC staff does not agree that the draft SE text would have precluded the use of Method 1 with surveillance-specific W(Z) functions, a footnote clarifying this position was added to Section 4.1.1 of the SE, since the staff intent is consistent with the concern expressed in the comment.
22	42	*…percent, …*	Change accepted.
23	10	*…they are associated with ~~connected to~~ the power level reductions….*	Change accepted.
23	36	*…licensees do not implement ~~have eliminated the~~ AFD…*	Change accepted.
24	4	*…based on NRC approved RAOC or CAOC ~~maneuvering analyses~~ analysis methodologies.*	Replaced "…based on maneuvering analyses." With "…based on RAOC or CAOC analysis methodologies that have been approved for use by the NRC staff."

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24	31 – 32	*...limit may result in ~~be needed associated with~~ some control rod:...*	*...limit may result in ~~be needed associated with some~~ control rod...*
25	28	*...of ~~new surveillances~~ SR 3.2.1.1 and SR 3.2.1.2.*	*...of ~~new surveillances~~ SRs 3.2.1.1 and 3.2.1.2.*
25	40	*...movement, ~~surveillance~~ SR 3.2.1.1 and SR 3.2.1.2 will be...*	*...movement, ~~surveillance~~ SRs 3.2.1.1 and 3.2.1.2 will be...*
26	7 – 11	Editorial changes throughout paragraph.	Changes accepted.
26	17	*...may indicate a ~~serious~~ core anomaly...*	Change accepted.
26	44 – 45	Delete sentence.	Change accepted.
28	2 – 19	See Attachment 1.	Attachment 1 proposed and justified a revision to the Frequency requirements to SR 3.2.1.2. The NRC staff updated the Draft SE to reflect this justification.
28	23	*...increasing the ~~f~~Frequency...*	Change accepted.
29	11	*...provided in the response to RAI 6 ~~by PWROG~~...*	Change accepted.
30	1 – 29	See comment for Page 28, Lines 2 – 19.	Per discussion above, the NRC staff updated the Draft SE to reflect the proposed changes and justification provided in Attachment 1.
31	32	*...Required Action B.1.1,...*	Change accepted.
32	1 – 3	Delete sentence.	Change accepted.
33	24	*...assumed in the RAOC or CAOC ~~maneuvering~~ analysis...*	Change accepted.
33	29 – 33	Editorial changes throughout paragraph.	Changes accepted.

WCAP–17661, "Improved RAOC and CAOC FQ Surveillance Technical Specifications"
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35	6 – 20	See comment for Page 28, Lines 2 – 19.	Per discussion above, the NRC staff updated the Draft SE to reflect the proposed changes and justification provided in Attachment 1. Based on its review of Attachment 1, the NRC staff determined that the limitation that was the subject of this comment could be eliminated.
35	37 – 40	See comment for Page 22, Lines 16 – 21.	Clarifying language added to limitation.
38	A_{XY}	Delete, "May be included in the COLR," because additional methods for determining factor were deleted from the Topical Report in the response to RAI 15.	NRC staff determined that entire sentence, "May be included in the COLR, could also be calculated using a 3-D score simulator for specific surveillance condition," was too detailed and could be deleted from table entry.
38	A_O	Add description similar to that contained in table entry immediately above.	Change accepted.
42		For table entry "SR 3.2.1.2, 1st requirement in the Frequency column," see comment at Page 28, Lines 2 – 19.	Table entry changed consistent with proposed revision contained in Attachment 1.

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Domestic		Units				Reactor Type	Participation		No. Shares Per Plant	Vote: Y/N/ Absent
Utility	**Plant Site**	**1**	**2**	**3**	**4**		**Original**	**Revision**		
Ameren Missouri	Callaway	**X**				W	**Y**	**Y**	1.00	Y
American Elec Power Co.	Cook	**X**	**X**			W	**Y**	**Y**	1.25	Y
Arizona Public Service Co.	Palo Verde					CE			0.00	
Dominion Nuclear Ct.	Millstone			**X**		CE W	**Y**	**N**	0.00	N
Dominion VA Power	North Anna	**X**	**X**			W	**Y**	**N**	0.00	N
	Surry	**X**	**X**			W	**Y**	**Y**	1.25	Y
Duke Energy Carolinas	Catawba					W			0.00	
	McGuire					W			0.00	
	Oconee					B&W			0.00	
Duke Energy Progress	Robinson					W			0.00	
	Shearon Harris					W			0.00	
Entergy Nuclear Northeast	Indian Point					W			0.00	
Entergy South	Waterford					CE			0.00	
	ANO					B&W CE			0.00	
Entergy – Palisades	Palisades					CE			0.00	
Exelon Generation Co, LLC	Braidwood	**X**	**X**			W	**Y**	**Y**	1.25	Y
	Byron	**X**	**X**			W	**Y**	**Y**	1.25	Y
	Calvert Cliffs					CE			0.00	
	Ginna	**X**				W	**Y**	**Y**	1.00	Y
	TMI					B&W			0.00	
First Energy Nuclear Operating Co.	Beaver Valley	**X**	**X**			W	**Y**	**Y**	1.25	Y
	Davis-Besse					B&W			0.00	
NextEra/FPL Group	St. Lucie					CE			0.00	
	Turkey Point			**X**	**X**	W	**N**	**N**	0.00	
	Seabrook	**X**				W	**Y**	**Y**	1.00	Y
	Pt Beach	**X**	**X**			W	**Y**	**Y**	1.25	Y
Luminant	Comanche Peak	**X**	**X**			W	**Y**	**Y**	1.25	Y
Pacific Gas & Electric Co	Diablo Canyon	**X**	**X**			W	**Y**	**Y**	1.25	Y
PSEG Nuclear	Salem	**X**	**X**			W	**N**	**N**	0.00	
So. Carolina Elec & Gas Co.	V. C. Summer	**X**				W	**Y**	**Y**	1.00	Y
STP Nuclear Operating Co.	So Texas Project	**X**	**X**			W	**N**	**N**	0.00	
Southern Nuclear Operating Co.	Farley	**X**	**X**			W	**Y**	**Y**	1.25	Y
	Vogtle	**X**	**X**			W	**Y**	**Y**	1.25	Y
Tennessee Valley Authority	Sequoyah					W			0.00	
	Watts Bar	**X**	**X**			W	**Y**	**Y**	1.25	Y
Wolf Creek Nuclear Operating Co.	Wolf Creek	**X**				W	**Y**	**Y**	1.00	Y
XCEL Energy	Prairie Island	**X**	**X**			W	**Y**	**Y**	1.25	Y

*Project participants as of the date the final deliverable was completed. On occasion, additional members will join a project. Please contact the PWR Owners Group Program Management Office to verify participation before sending this document to participants not listed above.

PWR OWNERS GROUP MEMBER PARTICIPATION* FOR PROJECT PA-LSC-0795

Listing of PWROG International Member Units							
			Original Participant		Revision Participant		
PWROG Member	**Applicable Plant Sites**	**Units**	**Yes**	**No**	**Yes**	**No**	**Total Participating**
International:							
AXPO AG	Beznau 1 & 2 (W)	2		X		X	
EDF Energy	Sizewell B (W)	1		X		X	
Electrabel (Belgian Utilities)	Doel 1, 2 & 4, Tihange 1 & 3 (W)	5		X		X	
Electricite de France	58 Units	58		X		X	
Electronuclear ETN	ANGRA 1 (W)	1		X		X	
Emirates Nuclear Energy Corporation	Barakah 1 & 2	2		X		X	
EPZ	Borssele	1		X		X	
Eskom	Koeberg 1 & 2	2		X		X	
Hokkaido	Tomari 1, 2 & 3 (MHI)	3		X		X	
Japan Atomic Power Company	Tsuruga 2 (MHI)	1		X		X	
Kansai Electric Co., Ltd	Mihama 3, Ohi 1, 2, 3 & 4, Takahama 1, 2, 3 & 4 (W & MHI)	9		X		X	
Korea Hydro and Nuclear Power Corp.	Kori 1, 2, 3, & 4 (W) Hanbit 1 & 2 (W)	6		X		X	
	Hanbit 3, 4, 5 & 6 (CE) Hanul 3, 4, 5, & 6 (CE)	8		X		X	
Kyushu	Genkai 2, 3 & 4, Sendai 1 & 2 (MHI)	5		X		X	
Nuklearna Elektrarna KRSKO	Krsko (W)	1		X		X	
Ringhals AB	Ringhals 2, 3 & 4 (W)	3		X		X	
Shikoku	Ikata 2 & 3 (MHI)	2		X		X	
Spanish Utilities	Asco 1 & 2, Vandellos 2, Almaraz 1 & 2 (W)	5		X		X	
Taiwan Power Co.	Maanshan 1 & 2 (W)	2		X		X	
TOTAL PARTICIPATING:		117		0		0	0

* Project participants as of the date the final deliverable was completed. On occasion, additional members will join a project. Please contact the PWR Owners Group Program Management Office to verify participation before sending this document to participants not listed above.

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RECORD OF REVISIONS

Revision	Date	Description
0	November 2013	WCAP-17661-P/NP Original Issue.
1	November 2013	Corrected WCAP-17661-P/NP proprietary markings.
-A	February 2019	WCAP-17661-P/NP-A, Revision 1 includes the following changes: 1. Updated the title page to add the –A designation to identify that the Topical Report (TR) was approved by the Nuclear Regulatory Commission (NRC). 2. Updated the signature page. 3. Inserted the NRC transmittal letter and enclosed Final Safety Evaluation (FSE) after the signature page. 4. Updated the Legal, Copyright, and Distribution Notices. 5. Updated the PWROG member participation tables. 6. Updated the Acknowledgements. 7. Added Record of Revisions table. 8. Incorporated the following TR changes that were transmitted to the NRC via PWROG letter OG-16-273, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated September 13, 2016: • In response to RAI-1a: Revised the Bases for Technical Specification (TS) 3.2.1B and 3.2.1C (Appendix B and E) to add this paragraph: *If an FQ surveillance is performed at 100% RTP conditions, and both FQ C(Z) and FQ W(Z) exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.* • In response to RAI-2: Added the **bold** text to the Note for TS 3.2.1B and 3.2.1C (Appendix A and D) Condition A to read as follows: ....NOTE............... Required Action A.4 shall be completed whenever this Condition is entered. **SR 3.2.1.2 is not required** **to be performed if this Condition is entered**

Revision	Date	Description
		prior to THERMAL POWER exceeding 75% RTP after a refueling. • In response to RAI-3b: Added a discussion to the Bases for TS 3.2.1B and TS 3.2.1C (Appendix B and E) for SR 3.2.1.1 and SR 3.2.1.2 that incorporates the justification for the 24 hours allowed to perform these Surveillances. • In response to RAI-5a & 5c: The Required Actions for Condition B in both TS 3.2.1.B and 3.2.1.C (Appendix A and D) were revised to require the performance of SR 3.2.1.1 and SR 3.2.1.2 if the implementation of a new operating space results in the need to move the control rods in order to comply with a new rod insertion limit. Required Action B.1 became Required Action B.1.1 in both Technical Specifications, and a new Required Action B.1.2 was added to perform SR 3.2.1.1 and 3.2.1.2 with a required Completion Time of 72 hours. • In response to RAI-7b: The following paragraph was added to the Bases as the first paragraph for Required Action B.2.1 in TS 3.2.1B (Appendix B): *When FQ W(Z) exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the FQ W(Z) limit, then Required Action B.2.1 must be entered and THERMAL POWER must be limited to less or equal to 50% RTP and AFD limits must be reduced by the amounts specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.* • The following paragraph was added to the Bases as the first paragraph for Required Action B.2.1 in TS 3.2.1C (Appendix E): *When FQ W(z) exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. If the more restrictive CAOC operating spaces specified in the COLR are insufficient to ensure margin to the FQ W(z) limit, the THERMAL POWER must be limited to less than or equal to 50% RTP. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.* • The following paragraph was added to the Bases as the second paragraph for Required Action B.2.1 in TS 3.2.1B and TS 3.2.1C (Appendix B and E): *If the required FQ W(z) margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than 50% RTP will provide additional margin in the transient FQ by the required change in THERMAL POWER and*

Revision	Date	Description
		the increase in the FQ limit. This will ensure that the FQ limit is met during transient operation that may occur at or below 50% RTP. • In response to RAI-8: A discussion was added to the Bases for TS 3.2.1B and TS 3.2.1C (Appendix B and E) for SR 3.2.1.1 and SR 3.2.1.2 that incorporates the justification for the 24 hours allowed to perform these Surveillances. • In response to RAI-9a: The following sentence was added to the fourth paragraph in the Bases for SR 3.2.1.1 and as the second paragraph in Insert 4 in the Bases discussion for SR 3.2.1.2 in the Bases for TS 3.2.1B and TS 3.2.1C (Appendix B and E): *Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.* • In response to RAI-10: SR 3.2.1.1 and SR 3.2.1.2 Required Actions A.4 and B.2.4 (Appendix A and D) were revised to clarify that the intent of the Note is that the Surveillances be completed prior to increasing the limitation on THERMAL POWER. 9. Incorporated the following TR changes that were transmitted to the NRC via PWROG letter OG-18-35, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795", dated February 15, 2018: • In response to RAI-15a: Deleted WCAP-17661 Sections, text, and Tables that discussed Methods 3 and 4 for Generating $A_{XY}(z)$ and Method 3 for Generating AQ(z): – Table of Contents – deleted Sections 4.3.3, 4.3.4, and 7.3.3. – List of Tables – deleted Tables 4-1, 4-2, 4-3, and 4-4. – List of Tables – deleted titles of Tables 6-5, 6-6, 6-7, and 6-8. Kept Table numbers in the list to prevent renumbering of subsequent tables. – Section 4.3 – changed "several" to "two" (methods). – Deleted Sections 4.3.3 and 4.3.4. – Deleted Tables 4-1, 4-2, 4-3, and 4-4. Tables 4-5 and 4-6 were also deleted. Tables 4-5 and 4-6 were not included the List of Tables. – Section 6.4 – deleted 2 paragraphs that discussed content in deleted tables. – Deleted titles of, and contents of Tables 6-5, 6-6, 6-7, and 6-8. Kept Table numbers in the list to prevent renumbering of subsequent tables. – Deleted Section 7.3.3. • Revised the TS Bases discussion of how the $A_{XY}(z)$ and AQ(z) factors are applied when the FQW(z) Surveillance is performed for 3.2.1B and 3.2.1C "Insert 1" text (Appendix B and E) that was transmitted in letter OG-16-273. • Revised Section F.2.2.6 on Page F-2 (Appendix F- Sample COLR Input for a CAOC Plant) to include a limitation on the use of Method 1 if Control Bank D is inserted deeper than the predicted limiting elevation for FQ W(z).

Revision	Date	Description
		10. Incorporated the following TR changes that were transmitted to the NRC via PWROG letter OG-18-188, "Transmittal of the Response to the Revised Draft Safety Evaluation (DSE) for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795)", dated August 2, 2018: • Revised TS 3.2.1B and TS 3.2.1C (Appendix A and D) to change the initial Frequency for SR 3.2.1.2. • Revised the Bases for TS 3.2.1B and TS 3.2.1C (Appendix B and E) to change the initial Frequency for SR 3.2.1.2. • WCAP-17661-P/ WCAP-17661 text was revised on the following pages: - page xx, revised text to: "…the first FQ Surveillance following a refueling must be performed after exceeding 75% of RTP." - page 1-5, revised text to: "The first surveillance of FQ W(z), however, is not required until after 75% RTP is exceeded." - page 3-16, revised text describing the first Frequency for SR 3.2.1.2. - pages 5-5 and 5-6, revised text describing SR 3.2.1.2. - page 8-4, revised text describing SR 3.2.1.2. - page11-2, revised text to: "…the first surveillance of FQW(z) following a refueling be performed after exceeding 75% RTP." 11. Edited the following TR changes that were transmitted to the NRC via PWROG letter OG-18-188: • Appendix B, RAOC TS Bases, deleted redundant sentence from Insert 2 for Action B.2.1. • Appendix B, RAOC TS Bases, added date to Reference 6 (WCAP-17661-P-A). • Appendix D, CAOC TS, did not delete "is" from SR 3.2.1.2. • Appendix E, CAOC TS Bases, deleted redundant sentence from Insert 3 for Action B.2.1. • Appendix E, CAOC TS Bases, deleted "and AFD" from Insert 3 for Action B.2.1. • Appendix E, CAOC TS Bases, added date to Reference 6 (WCAP-17661-P-A). 12. Added Appendix G to include the historical correspondence associated with the TR review, including the PWROG responses to NRC requests for additional information (RAIs). 13. Added Appendix H to include editorial changes to the FSE.

LIST OF ACRONYMS AND SYMBOLS

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
AFD	Axial Flux Difference
ANC	Advanced Nodal Code
AO	Axial Offset
AOD	Axial Offset Deviation, also known as IFBA-induced power shift
ARO	All Rods Out
BL	Baseload (steady-state)
BOL	Beginning of Life
BU	Burnup
CAOC	Constant Axial Offset Control
CIPS	Crud Induced Power Shift
COLR	Core Operating Limits Report
COS	CAOC operating space, a unique combination of CAOC AFD band and RILs
D-In	Lead Control Bank (Bank D) Inserted
DNB	Departure from Nucleate Boiling
ΔAO	Delta-AO, the difference between the measured and predicted axial offset
ΔI	Delta-I (synonym for AFD)
EFPD	Effective Full Power Days
EFPM	Effective Full Power Month
EOL	End of Life
EQXE	Equilibrium Xenon
FAC	Final Acceptance Criteria
F_Q	Total Heat Flux Hot Channel Factor, peak to average power density in the core
$F_Q^C(z)$	Measured steady-state (surveillance) $F_Q(z)$ including uncertainties
$F_Q^W(z)$	"Measured" transient $F_Q(z)$ including uncertainties and the 1/P power scaling factor from the F_Q limit expression.
$F_Q^{Tr}(z)$	Analytical transient $F_Q(z)$ for non-equilibrium operation,
F_{XY}	Planar Radial Peaking Factor, peak to average power density in a radial core plane
HFP	Hot Full Power
IFBA	Integral Fuel Burnable Absorber
INPO	Institute of Nuclear Power Operations
LCO	Limiting Condition for Operation
LHS	Left-hand Side
LOCA	Loss of Coolant Accident

LIST OF ACRONYMS AND SYMBOLS (cont.)

MOL	Middle of Life
MTU	Metric Tons of Uranium
MWD	Megawatt Days
NRC	U.S. Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
P(z)	Core Average Axial Power Shape
P_{rel}	Core average relative power
PDMS	Power Distribution Monitoring System
PWROG	Pressurized Water Reactor Owners Group
RAOC	Relaxed Axial Offset Control
RCS	Reactor Coolant System
RHS	Right-hand Side
RILs	Rod Insertion Limits
ROS	RAOC operating space, a unique combination of RAOC AFD limits and RILs
RTP	Rated Thermal Power
SR	Surveillance Requirement
SS	Steady-state
SWD	Steps Withdrawn
TS	Technical Specification
T(z)	Analytical ratios used in the improved F_Q Surveillance formulation for RAOC plants to characterize the maximum transient P(z).
WD	Withdrawn as in Steps Withdrawn
W(z)	Analytical ratios used in the current F_Q Surveillance formulation to characterize the maximum expected increase in the surveillance $F_Q(z)$*Power relative to the non-equilibrium $F_Q(z)$*Power.

ACKNOWLEDGEMENTS

The author is indebted to a number of current and former colleagues who helped to develop and evolve the Westinghouse CAOC and RAOC power shape analysis methods and technical specifications over the past several decades. These include Wade Miller, Toshio Morita, Ed Spier, Noel Pogorzelski, Jeff Secker, Bill Carlson, and Richard D. Ankney. Any new endeavor is facilitated by knowledgeable colleagues who provide ideas, novel insights and perspective, constructive comments, and fruitful discussions. In this regard, the author is indebted to current Westinghouse colleagues Ho Lam, Dave Krieg, and Jeff Brown. Finally, the author is indebted to the Pressurized Water Reactor Owners Group (PWROG) Licensing Committee, and other supporting members of the PWROG utility organizations including Bob Florian and A. R. Burger who guided this project and provided valuable review comments and suggestions. Their perspectives and insights have enhanced this work.

EXECUTIVE SUMMARY

The purpose of F_Q Surveillance Technical Specifications (TSs) 3.2.1B and 3.2.1C in NUREG-1431, Volume 1 "Standard Technical Specifications - Westinghouse Plants: Specifications" (Reference 1), is to provide assurance that the heat flux hot channel factor, F_Q, will remain within the limits assumed in the plant safety analyses when the core is operated within its allowed operating space. Key operating space limits include the Rated Thermal Power (RTP), the control bank rod insertion limits (RILs), and the axial flux difference (AFD) limits. Together, these operating space limits restrict the range of potential non-equilibrium core power shapes during normal operation, thereby limiting the maximum non-equilibrium $F_Q(z)$ and the maximum local power density.

The current F_Q Surveillance formulation in Reference 1 relies on a combination of analytical factors and periodic measurements to provide assurance that core operation within the allowed operating space will be acceptable. When an F_Q surveillance is performed, the equilibrium $F_Q(z)$ is measured at or near steady-state conditions. This is then multiplied by an analytical factor, W(z), which characterizes the increase in $F_Q(z)$ for non-equilibrium operation. The result, when uncertainties are included, is the maximum postulated transient $F_Q(z)$, which is then compared to the $F_Q(z)$ limit.

This formulation works well for Constant Axial Offset Control (CAOC) plants (TS 3.2.1C in Reference 1), where the allowed deviation of the AFD about the natural hot full power (HFP) target AFD is fixed. [

]a,c

For Relaxed Axial Offset Control (RAOC) plants (TS 3.2.1B in Reference 1), however, this formulation is not as robust. [

]a,c

[

]a,c

This power shape sensitivity is especially problematic for part-power surveillances. Part-power surveillances are routinely performed during startup following a refueling, typically at core powers as low as ~30% power. The lead control bank is often partially inserted, and the xenon level has usually not fully reached equilibrium. Accurately predicting the surveillance power shape under these circumstances requires precise knowledge of the surveillance core conditions and reactor configuration.

In addition to these difficulties with the F_Q Surveillance formulation, there is an important shortcoming with the RAOC F_Q Surveillance (TS) itself. Required Action B.1 in the RAOC TS 3.2.1B (Reference 1) requires a reduction in the AFD envelope by ≥ 1% for each 1% that $F_Q(z)$ exceeds its limit. This Required Action, however, does not adequately restore F_Q margin in all circumstances. [

]^{a,c}

To briefly summarize, there are two primary issues with the current RAOC F_Q Surveillance formulation and TS 3.2.1B (Reference 1):

1. Sensitivity of the formulation to the differences between the measured and predicted surveillance power shapes at both nominal and part power conditions

2. Potential non-conservatisms in the AFD reduction required action

In the improved RAOC F_Q Surveillance formulation and TS, these issues are addressed as follows:

Instead of the requiring measurement of the $F_Q(z)$ for RAOC plants, the improved formulation will require measurement of $F_{XY}(z)$. These measured peaking factors are then multiplied by factors that characterize the maximum transient P(z) values postulated to occur during non-equilibrium operation. P(z) is the core average axial power shape. This formulation essentially eliminates the sensitivity of the surveillance to the surveillance axial power shape, but retains the essential feature of incorporating the measured radial peaking factors into the surveillance $F_Q(z)$ values.

This new formulation will also improve the accuracy of part-power surveillances. The improved F_Q Technical Specification, however, also revises the Frequencies of the TS by requiring that the first F_Q Surveillance following a refueling must be performed after exceeding 75% of RTP.

Finally, the improved RAOC F_Q Surveillance TS incorporates the concept of RAOC operating spaces. A RAOC operating space (ROS) is a unique combination of Control Bank Insertion Limits and AFD limits. In the improved F_Q TS, transient surveillance factors are pre-calculated for multiple RAOC operating space assumptions. The RAOC operating spaces are specified in the Core Operating Limits Report (COLR). If the F_Q limit is exceeded during a surveillance, a more restrictive RAOC operating space is implemented that provides the required additional F_Q margin for future operation. In the unlikely event that no RAOC operating space provides the required margin improvement, then thermal power limits and AFD reductions specified in the COLR must be implemented.

While the current F_Q Surveillance formulation works well for CAOC plants, a minor revision is made to this formulation to permit adjustment of the surveillance to the target axial offset (AO) core conditions. Also, the improved CAOC F_Q Surveillance TS incorporates the concept of operating spaces. The current CAOC F_Q Surveillance TS requires a power level reduction if the F_Q limit is exceeded. The improved F_Q TS provides the option of implementing a more restrictive CAOC operating space, which is defined as a unique combination of AFD band and Control Bank Insertion Limits. The CAOC operating spaces are specified in the COLR. The appendices provide the new RAOC and CAOC F_Q Surveillance Technical Specifications and Bases as well as sample COLRs.

1 INTRODUCTION

The purpose of this topical report is to present improved F_Q Surveillance TSs for RAOC and CAOC operation. New methodologies required to support these TS are also presented. These improved F_Q TSs are intended to replace the F_Q Surveillance TS presented in Reference 1 (TS 3.2.1B and TS 3.2.1C) and WCAP-10216-P-A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification" (Reference 5). It is intended that this topical report will be added to the Core Operating Limits Report TS as a methodology reference.

As discussed in depth in later sections, the F_Q Surveillance Technical Specification for CAOC plants (TS 3.2.1C in Reference 1) works well and, therefore, the proposed improvements to the CAOC F_Q Surveillance Technical Specification are not extensive. For the RAOC F_Q Surveillance Technical Specification (TS 3.2.1B in Reference 1), however, changes are needed to address some significant issues. These changes include a reformulation of the basic RAOC F_Q Surveillance mathematical expression and changes to the Required Actions of the Technical Specification. Changes to the Required Actions are needed to ensure margin recovery in the unlikely event that a surveillance indicates that the transient $F_Q(z)$ could exceed its limit.

As a prelude to the remainder of the report, the following background section provides a short historical overview of the F_Q Surveillance TS. It also briefly describes the issues with the current F_Q TS. These issues are described in more depth in Section 3. Section 1.2 gives an overview of the key attributes of the improved F_Q Technical Specifications and how these attributes address the issues with the F_Q Surveillance Technical Specifications of Reference 1. Section 1.3 provides a brief description of the remainder of the report.

1.1 BACKGROUND

The F_Q Surveillance Technical Specification provides assurance that the heat flux hot channel factor, F_Q, will remain within the limits assumed in the plant safety analyses when the core is operated within its allowed operating space. The allowed core operating space consists of the limits imposed by the Technical Specifications on the maximum allowable power level (i.e., the RTP), the control bank insertion limits, the axial flux difference, and the radial tilt.

TS 3.2.1B in Reference 1, "Heat Flux Hot Channel Factor $F_Q(z)$ (RAOC—W(z) Methodology)," is the RAOC version of the F_Q Surveillance Technical Specification, while TS 3.2.1C in Reference 1, "Heat Flux Hot Channel Factor $F_Q(z)$ (CAOC—W(z) Methodology)," is the CAOC version. While there is some variability in how these Technical Specifications have been implemented by individual utilities, most plant-specific F_Q Surveillance Technical Specifications include salient features that are very similar to those of the Technical Specifications described in Reference 1. Those features include, for example, surveillance of both steady-state $F_Q(z)$ and transient $F_Q(z)$, the use of W(z) factors in the COLR to characterize the expected increase in the steady-state $F_Q(z)$ due to non-equilibrium operation (e.g., load follow), a reduction of the AFD operating space for RAOC plants when the transient F_Q limit is exceeded, and a reduction in the thermal power when the transient F_Q limit is exceeded for CAOC plants. In this topical report, the Reference 1 versions of these specifications will serve as the basis for discussion. Proposed improvements will be described relative to these versions.

It is useful to briefly review the history of the Heat Flux Hot Channel Factor Technical Specification to understand some of the reasons why the specification has evolved to its present form. (See Section 2 for definitions and descriptions of some of the key terms used in this discussion and the overview discussion in Section 1.2.)

Early versions of the Heat Flux Hot Channel Factor Technical Specification simply required periodic measurement of $F_Q(z)$. This measurement was compared to the limit value, which was (and typically still is) set by the requirements of the Large Break Loss of Coolant Accident. If the $F_Q(z)$ limit was met during the surveillance, operation could continue within the allowed operating space until the next required surveillance, which typically occurred after 31 Effective Full Power Days (EFPD).

Since flux map measurements of the core power distribution are taken at steady-state or near steady-state conditions, this early version of the specification did not explicitly account for non-equilibrium operation of the core as part of the surveillance formulation and the effect that such operation could have on $F_Q(z)$. Non-equilibrium operation—load follow, for example—can cause substantial increases in axial power peaking, and hence, the $F_Q(z)$. During this time, the 1970s and early 1980s, virtually all Westinghouse Electric Company Nuclear Steam Supply System (NSSS) plants employed the CAOC power distribution control strategy. For these plants, F_Q limit confirmation for non-equilibrium operation was essentially an analytical process in which CAOC operation was simulated for various load follow strategies (see WCAP-8385 (Proprietary) and WCAP-8403(Non-Proprietary), "Topical Report Power Distribution Control and Load Following Procedures" [Reference 2], Westinghouse Letter NS-CE-687 [Reference 3], and NS-TMA-2198, Attachment: "Operation and Safety Analysis Aspects of an Improved Load Follow Package" [Reference 4]). This CAOC analysis, also referred to as the Final Acceptance Criteria (FAC) analysis, provided the maximum expected $F_Q(z)$ for CAOC operation. If the maximum $F_Q(z)$ value resulting from this analysis met the loss of coolant accident (LOCA) $F_Q(z)$ limit, then operation within the AFD band was acceptable assuming that other applicable limits, such as fuel centerline melt, were also met.

A more robust surveillance method was developed and implemented in the late 1970s. This surveillance method, known as F_{XY} Surveillance, is still being used today by some CAOC plants. TS 3.2.1A in Reference 1, "Heat Flux Hot Channel Factor $F_Q(z)$ (CAOC—F_{XY} Methodology)," gives this version of the $F_Q(z)$ specification. This method accounts for non-equilibrium operation implicitly by specifying the maximum allowable $F_{XY}(z)$ value that would be permissible within the context of non-equilibrium operation. Essentially, the most limiting axial power shapes from the CAOC analysis are used to determine the $F_{XY}(z)$ limit values such that, when applied to the limiting axial power shapes, the $F_Q(z)$ limit would just be met. The core $F_{XY}(z)$ values are periodically measured throughout the operating cycle and compared to the limit values, which are specified in the COLR usually as a function of cycle burnup. If the measured $F_{XY}(z)$ values are less than the limit $F_{XY}(z)$ values, then operation within the $F_Q(z)$ limit is assured for non-equilibrium CAOC operation. This is an implicit confirmation of the F_Q limit since the maximum transient $F_Q(z)$ is not explicitly determined in this formulation. [

]^{a,c} In the improved RAOC F_Q Surveillance Technical Specification, however, the "measured" maximum transient $F_Q(z)$ value is explicitly determined and compared to its limit, directly accounting for the potential effects of non-equilibrium operation.

In the early 1980s, the RAOC power shape methodology was developed primarily to provide a larger operating space and, hence, enhanced operating flexibility for the reactor core relative to CAOC operation. Reference 5 describes the RAOC power shape methodology. The F_Q Surveillance methodology was also developed at this time. The initial implementation of F_Q Surveillance is also described in Reference 5. The F_Q Surveillance methodology, however, is not limited to RAOC plants. As indicated above, Reference 1 contains both RAOC and CAOC versions of this specification.

The current F_Q Surveillance Technical Specification and its shortcomings will be described more completely in later sections. Briefly, this specification accounts for non-equilibrium operation through a factor called W(z). W(z) can be thought of as the analytical ratio, at a given elevation, of the maximum power density for non-equilibrium operation and the maximum power density for equilibrium (steady-state) operation at the surveillance condition. This ratio, determined using the power shapes from the RAOC and CAOC power shape analyses, is calculated as a function of core height and is provided in the COLR for several different cycle burnups. The surveillance is performed by measuring the steady state $F_Q(z)$ at the surveillance condition and multiplying this function by W(z). When appropriate uncertainties are included, the result is the maximum expected transient $F_Q(z)$, which can then by compared to the limit value.

For both CAOC and RAOC plants, the current F_Q Surveillance Technical Specification represents a significant improvement over the earliest F_Q specification since the postulated effects of non-equilibrium operation are explicitly accounted for through the W(z) factors. For CAOC plants, this formulation is reasonably robust. This is not the case, however, for RAOC plants. [

]^{a,c}

Regardless of whether CAOC or RAOC TSs are employed, exceeding the F_Q limit during an F_Q Surveillance is an uncommon occurrence. For CAOC plants, a power reduction is required by the CAOC Technical Specification if the transient F_Q limit is exceeded. A reduction in the power level effectively reduces the maximum expected power density for a given maximum expected transient F_Q for non-equilibrium CAOC operation. For RAOC plants, the current Technical Specification requires a reduction of ≥1% in the positive and negative AFD limits for each 1% that the transient $F_Q(z)$ exceeds its limit (Required Action B.1). The effect of reducing the AFD operating space is to limit the range of possible non-equilibrium power shapes. In particular, the potential for the most highly skewed non-equilibrium axial shapes to occur is eliminated when the AFD operating space is reduced. These highly skewed power shapes often produce the largest transient F_Q values.

To restore margin, reducing the RAOC AFD operating space works well in most instances. There are cases, however, where this Required Action does not provide a significant margin improvement for non-equilibrium operation. [

]^{a,c} This is discussed in more detail in Section 3. NSAL-09-5, "Relaxed Axial Offset Control F_Q Technical Specification Actions" (Reference 6) informed affected utilities of the potential non-conservatism in this Required Action and provided interim actions should the transient F_Q limit be exceeded during a surveillance.

The intent this discussion is to provide some historical context for the current F_Q Surveillance Technical Specifications and to discuss the two primary issues in the RAOC version of this Technical Specification, namely:

1. The sensitivity of the surveillance to differences between the measured and predicted surveillance axial power shapes at both nominal and part power conditions

2. The potential non-conservatism in Required Action B.1, which requires a reduction in the RAOC AFD operating space when the F_Q limit is exceeded

The first item can lead to over-predictions or under-predictions of F_Q margin, depending on the nature of the power shape misprediction and the limiting margin location. In turn, under-predictions of margin may lead to anomalous F_Q violations, i.e., F_Q violations that are not true violations but are simply the result of the arithmetic used in the F_Q Surveillance formulation that results in this sensitivity to the differences between the measured and predicted axial power shapes. This has been a particular problem for part-power surveillances. [

]^{a,c}

Consequently, the issue with the current RAOC F_Q Surveillance Technical Specification is that there is significant potential for anomalous F_Q violations to result in reductions in the maximum allowable power level when the measured and predicted surveillance axial power shapes disagree.

As discussed in Section 1.2, the primary objective of this report is to address these issues with the current RAOC F_Q Surveillance Technical Specification. In addition, other minor improvements in both the RAOC and CAOC F_Q Surveillance Technical Specifications are proposed.

1.2 OBJECTIVES AND OVERVIEW

The objectives of this report are to present improved versions of both the RAOC and CAOC F_Q Surveillance Technical Specifications, to describe in detail how these improved versions address the issues with the current F_Q Technical Specifications, and to describe the methodologies that will be used to support these improved F_Q Technical Specifications. The proposed Technical Specifications are provided along with their associated bases. In addition, sample COLR inputs associated with these Technical Specifications are provided. A brief overview of the key attributes of the improved F_Q Technical Specifications follows.

For RAOC, the improved F_Q Surveillance Technical Specification addresses the issues described in the previous section by reformulating the transient F_Q Surveillance expression and defining new Required Actions that ensure adequate margin recovery. As part of this reformulation, the F_Q Surveillance W(z) factors are redefined to mitigate the sensitivity to differences between the measured and predicted steady-state power shapes. The new factors, called T(z) factors, primarily characterize the maximum transient P(z), i.e., the maximum expected values of the normalized core average axial power shape

resulting from non-equilibrium operation. In the new formulation, the radial $F_{XY}(z)$ peaking factors are measured and multiplied by the T(z) factors to obtain the "measured" $F_Q^W(z)$, which is the transient $F_Q(z)$. The measured steady-state axial power shape is not used in the surveillance, nor is the predicted surveillance axial power shape. This new formulation will also improve the accuracy of part-power surveillances since the surveillance axial power shape is not used to determine the measured transient $F_Q(z)$. Use of the surveillance axial power shape in the part-power transient $F_Q(z)$ measurement is a major source of the "over-measurement" that can lead to anomalous reductions in transient F_Q margin for part-power surveillances.

To address the non-conservatism in Required Action B.1, the improved RAOC F_Q Technical Specification is structured to permit multiple RAOC operating spaces to be defined in the COLR. The COLR will include T(z) functions for each RAOC operating space, which is defined as a unique combination of AFD limits and control bank insertion limits. If the plant measures a transient F_Q violation, then a more restrictive RAOC operating space can be selected from the COLR that provides the required margin for future non-equilibrium operation. This retains the feature of using an AFD reduction to gain margin, but in a manner that ensures that appropriate margin is recovered. If none of the RAOC operating spaces included in the COLR provides the required margin, then limits on thermal power and AFD must be implemented. These limits are specified in the COLR. The analysis methods used to determine the T(z) values are described in this report as are the methods used to determine the limits on thermal power and AFD.

The new RAOC F_Q Surveillance Technical Specification also improves and clarifies the Surveillance Requirements. Following a refueling, the improved F_Q Technical Specification requires a surveillance of the current $F_Q(z)$, $F_Q^C(z)$, prior to exceeding 75% RTP. The first surveillance of $F_Q^W(z)$, however, is not required until after 75% RTP is exceeded. The current F_Q TS specifies that the first surveillance of $F_Q^W(z)$ should occur prior to exceeding 75% RTP. Also, the rigor of accounting for transient peaking factor increases between surveillances is improved in the new Technical Specification by tying the application of the penalty factor that accounts for the peaking factor increase between surveillances directly to predicted $F_Q^W(z)$ margin reductions for operation during the next surveillance interval (31 EFPD). The current F_Q specification requires application of the penalty factor only if $F_Q^C(z)/K(z)$ has increased over the <u>previous</u> surveillance interval, where K(z) is the axial shape function for the $F_Q(z)$ limit. Consequently, the improved F_Q TS will better account for the expected future margin trend.

The new version of the CAOC F_Q Surveillance Technical Specification improves the specification by providing an alternative to a power reduction when the transient F_Q limit is exceeded. The current Required Action B.1 of Technical Specification 3.2.1C (Reference 1) requires a $\geq$ 1% power reduction for each 1% that $F_Q^W(z)$ exceeds its limit. In the new version of the CAOC F_Q Surveillance Technical Specification, a more restrictive CAOC operating space may be implemented instead of a power reduction. A CAOC operating space is a unique combination of CAOC AFD band limits and control bank insertion limits. The COLR will include pre-analyzed CAOC operating spaces representing successively more restrictive operating spaces that provide commensurate improvements in F_Q margin for non-equilibrium operation.

If none of the CAOC operating spaces included in the COLR provides the required margin, new Required Action B.2.1 requires limiting the core thermal power to less than the RTP. The magnitude of the required reduction in the maximum allowable thermal power will be specified in the COLR. This new Required

Action includes a minor correction to current Required Action B.1, which specifies a reduction in thermal power, not maximum allowable thermal power, when the $F_Q^W(z)$ limit is exceeded. As discussed later in the report, limiting the maximum allowable thermal power is the appropriate action when sufficient margin is not restored through a reduction in the CAOC operating space because operation at RTP is always limiting for CAOC operation.

The improved CAOC F_Q Surveillance Technical Specification also improves and clarifies the Surveillance Requirements for TS 3.2.1C (Reference 1). The changes are the same as those described above for the improved RAOC F_Q Surveillance Technical Specification.

The overall intent of this report, therefore, is to address existing issues with these Technical Specifications and to implement minor improvements to make them more rigorous as well as more usable within the context of typical and expected plant operation.

1.3 REPORT SUMMARY

The remainder of the report is structured as follows:

Section 2 describes in detail some key concepts and terms used throughout the report. Section 3 discusses the current F_Q Surveillance formulation. In this section, the current F_Q Surveillance formulation is derived and the mathematical basis for the sensitivity to differences between the measured and predicted steady-state axial power shapes is discussed. This section provides a detailed discussion of the issues with the current formulation and specifications. Section 4 discusses the improved RAOC F_Q Surveillance formulation. The mathematical basis for the new formulation is established and related to the current formulation. The analysis methodology required to support the new formulation is described. Section 5 discusses the improved RAOC F_Q Surveillance Technical Specification. Section 6 provides the results of a sample RAOC F_Q Surveillance analysis, which illustrates how the improved RAOC F_Q Surveillance Technical Specification will function. The RAOC operating spaces selected for analysis and the resulting T(z) factors are described. This section also applies the improved F_Q Surveillance formulation to a flux map. Sections 7 and 8 discuss the improved CAOC F_Q Surveillance formulation and Technical Specification, respectively. The change to the CAOC F_Q Surveillance formulation discussed in Section 7 is relatively minor and involves the inclusion of a factor that permits adjustment of the surveillance to the CAOC Target AO core conditions. Section 9 gives the results for a sample CAOC F_Q Surveillance analysis with multiple CAOC operating spaces. Section 10 discusses implementation of these improved F_Q Technical Specifications. In particular, some of the potential variations are briefly described, such as implementation at plants that utilize the BEACON™ [1] Core Monitoring System. Section 11 gives a brief summary and conclusion, and Section 12 lists the report references. Finally, there are six appendices in the report. Appendices A and B give the proposed text for the improved RAOC F_Q Surveillance Technical Specification and Bases. Appendix C provides sample RAOC COLR input. Appendices D, E, and F provide the same information but for the improved CAOC F_Q Surveillance TS.

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2 KEY CONCEPTS AND DEFINITIONS

Definitions and descriptions of some of the key concepts used in this report are provided in this section.

Heat Flux Hot Channel Factor, F_Q

F_Q is the heat flux hot channel factor. There are several equivalent means of defining the heat flux hot channel factor. For the purposes of this report, the most useful definition gives F_Q in terms of the local power density. The F_Q at any point (x_0, y_0, z_0) in the core is the ratio of the power density at that point in the core to the core average power density. Symbolically, this can be expressed as follows:

$$F_Q(x_0, y_0, z_0) = \frac{p(x_0,y_0,z_0)}{\frac{1}{V}\iiint p(x,y,z)\, dxdydz} \quad (2\text{-}1)$$

where:

$p(x_0, y_0, z_0)$ is the local power density at position (x_0, y_0, z_0) and V is the total core volume.

The denominator in expression (2-1) is simply the core average power density, $\overline{p(x,y,z)}$. So, expression (2-1) can be rewritten as follows:

$$F_Q(x_0, y_0, z_0) = \frac{p(x_0,y_0,z_0)}{\overline{p(x,y,z)}} \quad (2\text{-}2)$$

For a given three-dimensional core power distribution, there will be some point in the core where the power density is a maximum. This point determines the maximum F_Q of the core. Therefore,

$$F_Q = \frac{Max\ p(x,y,z)}{\overline{p(x,y,z)}} \quad (2\text{-}3)$$

For many cores, the limit for the heat flux hot channel factor is given as a function of z, where z is the axial core dimension. Therefore, it is useful to define the limiting F_Q at a particular elevation z_0 as follows:

$$F_Q(z_0) = \frac{Max\ over\ x,y\ of\ p(x,y,z_0)}{\overline{p(x,y,z)}} \quad (2\text{-}4)$$

Planar Radial Peaking Factor, F_{XY}

The planar radial peaking factor, F_{XY}, is a component of F_Q. $F_{XY}(z)$ measures the relative power peaking in a given axial plane and is defined as the ratio of the peak-to-average power density in the plane. Symbolically, the F_{XY} at elevation z_0 is expressed as follows, where A is the radial core area:

$$F_{XY}(z_0) = \frac{Max\ over\ x,y\ of\ p(x,y,z_0)}{\frac{1}{A}\iint p(x,y,z_0)\, dxdy} \quad (2\text{-}5)$$

Core Average Axial Relative Power, P(z)

The core average axial relative power, P(z), quantifies the ratio of the average power density in a given radial plane of the core relative to the average power density of the core. Like F_{XY}, P(z) is a component of F_Q. Symbolically, the core average relative axial power at elevation z_0 is expressed as the following ratio:

$$P(z_0) = \frac{\frac{1}{A}\iint p(x,y,z_0)\,dxdy}{\frac{1}{V}\iiint p(x,y,z)\,dxdydz} = \frac{\frac{1}{A}\iint p(x,y,z_0)\,dxdy}{\overline{p(x,y,z)}} \qquad (2\text{-}6)$$

P(z), then, characterizes the axial power shape of the core.

$F_Q(z)$ Synthesis

From (2-5) and (2-6), the product of $F_{XY}(z_0)$ and $P(z_0)$ is given by the following:

$$F_{XY}(z_0) * P(z_0) = \frac{Max\ over\ x,y\ of\ p(x,y,z_0)}{\frac{1}{A}\iint p(x,y,z_0)\,dxdy} * \frac{\frac{1}{A}\iint p(x,y,z_0)\,dxdy}{\overline{p(x,y,z)}} \qquad (2\text{-}7)$$

Simplifying, this becomes:

$$F_{XY}(z_0) * P(z_0) = \frac{Max\ over\ x,y\ of\ p(x,y,z_0)}{\overline{p(x,y,z)}} \qquad (2\text{-}8)$$

Comparing (2-8) and (2-4) gives the following identity:

$$F_Q(z_0) = F_{XY}(z_0) * P(z_0) \qquad (2\text{-}9)$$

This expression shows that the F_Q at any point in the core can be determined from the product of the planar radial peaking factor for that point in the core and the axial relative power for the corresponding elevation. In general, then:

$$F_Q(z) = F_{XY}(z) * P(z) \qquad (2\text{-}10)$$

This F_Q synthesis expression is the basis for F_Q Surveillance. As described in Reference 2, bounding $F_{XY}(z)$ values based on two-dimensional (2D) core models were originally used in this synthesis methodology for analytical estimates of transient $F_Q(z)$. With the advent of modern three-dimensional (3D) nodal methods, however, $F_{XY}(z)$ values for the synthesis are obtained directly from 3D core models for analytical estimates of transient $F_Q(z)$. Transient P(z) power shapes are typically obtained from a one-dimensional (1D) core model and synthesized with $F_{XY}(z)$ values from a 3D core model to estimate transient $F_Q(z)$. However, it is also possible to simulate transients using the 3D core model, thereby obtaining transient $F_Q(z)$ estimates directly from the 3D core model.

The improved RAOC F_Q Surveillance formulation described in this report employs expression (2-10) as the basis for surveillance of the transient $F_Q(z)$ through the use of measured $F_{XY}(z)$ values and through analytical factors that characterize the maximum transient P(z). This will be discussed in more detail in Sections 3 and 4.

Most Westinghouse NSSS plants do not employ continuous monitoring of the 3D core power distribution. Instead, as required by the Technical Specifications, periodic surveillances are performed (usually every 31 EFPD). For the surveillance, a flux map or a calibrated core model is used to measure the core power distribution. The core is generally operating at or near steady-state conditions at this time. As such, the surveillance axial power shape will not reflect the limiting axial power shapes that could occur during non-equilibrium operation, e.g., during load follow. In other words, the P(z) component of the measured $F_Q(z)$ will reflect the steady-state condition of the measurement, not the limiting transient axial power shapes that are theoretically possible during non-equilibrium operation within the allowed operating space.

As described in Reference 5, pre-calculated analytical factors are used to account for the effects of transient axial power shapes. These factors, called W(z) factors, quantify the increase in the steady-state surveillance $F_Q(z)$ due to non-equilibrium operation. As such, they include the increased peaking factor effects of the transient axial power shapes, i.e., the transient P(z). The W(z) factors also account for changes in the $F_{XY}(z)$ component of $F_Q(z)$ due to non-equilibrium operation, e.g., increases in $F_{XY}(z)$ caused by control rod insertion or operation at part power. In general, however, transient $F_{XY}(z)$ has only a small effect on the transient $F_Q(z)$. Transient P(z) is the F_Q component that drives $F_Q(z)$ to limiting values.

As will become clear in Section 3, [

]^{a,c} This is tantamount to normalizing the predicted $F_{XY}(z)$ values to the measured $F_{XY}(z)$. The present F_Q Surveillance formulation does this indirectly through the product of the W(z) factors and the measured steady-state $F_Q(z)$. As will be discussed in Section 3, this method introduces a sensitivity to differences between the measured and predicted axial power shape that can distort the surveillance.
[

]^{a,c}

For CAOC plants, the situation is slightly different. For CAOC plants, the current F_Q Surveillance formulation works reasonably well and is not sensitive to the differences between measured and predicted steady-state power shapes. [

]^{a,c}

These differences in the efficacy of the current F_Q Surveillance formulation for RAOC and CAOC operation are due to fundamental differences in the axial flux difference limits for these two operating strategies. The following describes these differences.

Axial Offset and Axial Flux Difference

AO and AFD are quantities used to characterize and control the core average axial power shape, P(z). The AO is defined as follows:

$$AO = \frac{P_T - P_B}{P_T + P_B} \quad (2\text{-}11)$$

where:

P_T is the total power produced in the top half of the core and P_B is the total power produced in the bottom half of the core.

AO, therefore, is a measure of the skewness of the axial power shape. Top-peaked shapes will have large positive AO values. Bottom-peaked shapes will have large negative AO values. Highly skewed power shapes tend to have large P(z) values. This translates into large F_Q values. Such shapes may be limiting with respect to margin if they occur at high power levels.

AO is normally given in terms of percent of the total power, P_{TOT}, i.e.:

$$AO(\%) = \frac{P_T - P_B}{P_T + P_B} * 100\% = \frac{P_T - P_B}{P_{TOT}} * 100\% \quad (2\text{-}12)$$

Axial flux difference (which is sometimes referred to as Delta-I (ΔI), Delta-flux, or simply flux difference) is related to axial offset and is the axial power distribution parameter continuously monitored at the plant. It is also used as an input to the core protection system. Limits on the axial flux difference are provided in the Technical Specifications to ensure that axial power shapes are maintained within the range considered in the core safety analyses.

AFD is defined as the difference between the power in the top of the core and the power in the bottom of the core as a percent of P_{RTP}, the Rated Thermal Power. Therefore,

$$AFD = \frac{P_T - P_B}{P_{RTP}} * 100\% \quad (2\text{-}13)$$

If we define the core relative power as

$$P_{rel} = \frac{P_{TOT}}{P_{RTP}} \quad (2\text{-}14)$$

then, from (2-12) and (2-13), AFD and AO are related by the following expression:

$$AFD = AO * P_{rel} \quad (2\text{-}15)$$

[ ]a,c The CAOC and RAOC strategies will now be briefly discussed.

CAOC Operation

The current CAOC AFD Technical Specification (see TS 3.2.3A, "AXIAL FLUX DIFFERENCE (AFD) (Constant Axial Offset Control (CAOC) Methodology)" of Reference 1) limits the range of possible non-equilibrium axial power shapes by constraining the AFD to a tolerance band about the natural target AFD. The natural target AFD is periodically updated and measured at equilibrium xenon, HFP conditions and with the lead control bank at its normal position (only slightly inserted into the core). This measured target AFD will vary with cycle burnup and may be slightly different than the predicted target.

Figure 2-1 shows a typical target AFD band. Below 90% RTP, the AFD is permitted to be outside of the target band, but only for a limited period of time. At all times, the AFD must be within the acceptable operation limits defined in the figure. The CAOC AFD Technical Specification requires accumulation of penalty deviation minutes when AFD is outside of its target band but within the acceptable operation limits. If greater than one hour of penalty deviation minutes is accumulated, a power reduction to below 50% is required.

In Figure 2-1, the example target AFD is a linear function from -3% at full power to 0% at zero power. For this example, then:

$$Target\ AFD(\%) = -3\% * P_{rel} \tag{2-16}$$

From expression (2-15) we have

$$AO = \frac{AFD}{P_{rel}} \tag{2-17}$$

Inserting (2-16) into (2-17) gives:

$$Target\ AO(\%) = \frac{Target\ AFD(\%)}{P_{rel}} = \frac{-3\% * P_{rel}}{P_{rel}} = -3\% = constant \tag{2-18}$$

Consequently, the target AFD, which is a linear function of power level, represents a line of constant axial offset. Operation at or near this target line (e.g., within the tolerance band) will limit the range of axial power shapes and axial xenon shapes that are produced during non-equilibrium operation. In turn, this will limit transient $F_Q(z)$. In the $F_Q(z)$ synthesis expression (2-10), the $F_{XY}(z)$ component is largely determined by the core loading pattern; the operator has little control over its value. By contrast, during non-equilibrium operation, the P(z) component of expression (2-10) is greatly influenced by how the core is controlled. The essential purpose of CAOC operation is to maintain tight control on P(z) so as to limit the large axial power peaking that can result from extreme swings in the axial power shape and axial xenon shape. In the CAOC analysis methodology (References 2, 3, and 4), load follow simulations are performed in which the AFD is constrained to the narrow band about the AFD target. The simulations serve to generate non-equilibrium xenon shapes and rodded power shapes consistent with standard load follow maneuvers. The objective of the analysis is to confirm that operation within the CAOC AFD band operating space will not result in transient $F_Q(z)$ values that exceed the limit.

An important aspect of CAOC power distribution control is that the maximum deviation of the AFD relative to the target is fixed by the AFD tolerance band. Regardless of whether the target AFD is 0%, +3%, or -3%, the deviation relative to the target is the same. This fact has implications for the mathematics of the CAOC F_Q Surveillance formulation, which captures the peaking factor effects of this allowed deviation through the W(z) factor. Additional discussion of this will be provided in Section 3.

RAOC Operation

AFD control in RAOC operation is not limited to a narrow band about a target AFD value. Instead, the AFD envelope is fixed and significantly larger than for a typical CAOC AFD operating band. Figure 2-2 shows a representative RAOC AFD envelope. For comparison, superimposed on this figure is the ±5% CAOC AFD band from Figure 2-1.

In RAOC, operation anywhere within the allowed envelope is acceptable. Furthermore, there are no AFD limits below 50% RTP. As part of the reload safety evaluation that is routinely performed for each operating cycle, the AFD envelope is analyzed using the methodology of Reference 5. Briefly, this methodology entails generating a xenon shape library through load swing calculations. Next, normal operation power shapes are generated for combinations of xenon shape, control rod insertion, and core power level. The intent is to populate the AFD operating space with a robust set of power shapes and confirm that power shapes within the allowed AFD operating space will have acceptable $F_Q(z)$ values. The AFD envelope is adjusted, as necessary, until all the power shapes within the AFD envelope are acceptable.

Unlike during CAOC operation, the AFD envelope is fixed during RAOC operation and does not move relative to the natural axial offset of the core. [

]^{a,c} Mathematical aspects of this sensitivity will be discussed in Section 3.

Periodic surveillances are performed during operation to demonstrate that the limits on the transient $F_Q(z)$ will continue to be met given the actual steady-state core radial peaking factors that are present in the core. [ ]^{a,c}

[

]^{a,c}

$F_Q(z)$ Limit

For Westinghouse NSSS plants, the F_Q limit, which is generally set by the LOCA analysis, is a function of both power level and elevation. The F_Q limit is typically provided in the COLR. Figure 2-3 illustrates a typical limit.

The elevation dependence of the F_Q limit is characterized by the K(z) function. The K(z) function is the normalized $F_Q(z)$ limit and has a maximum value of 1.0. Figure 2-3 shows a typical K(z) function. With respect to power level, the F_Q limit is inversely proportional to power between 50% and 100% RTP. At or below 50% RTP, the limit is a constant function of power. Typical limits for $F_Q(z)$ are:

$$F_Q(z) \le \frac{CFQ}{P_{rel}} * K(z) \quad for\ P_{rel} > 0.5 \tag{2-19}$$

$$F_Q(z) \le \frac{CFQ}{0.5} * K(z) \quad for\ P_{rel} \le 0.5 \tag{2-20}$$

where:

P_{rel} is the fraction of RTP and CFQ is the $F_Q(z)$ limit magnitude at HFP.

A typical value for CFQ is 2.50. As previously stated, this value is set by the LOCA analysis. Figure 2-3 gives a representative HFP $F_Q(z)$ limit assuming CFQ equals 2.50.

The above two expressions can be rearranged slightly as follows:

$$F_Q(z) * P_{rel} \le CFQ * K(z) \quad for\ P_{rel} > 0.5 \tag{2-21}$$

$$F_Q(z) * 0.5 \le CFQ * K(z) \quad for\ P_{rel} \le 0.5 \tag{2-22}$$

The peak power density at elevation z is proportional to the term $F_Q(z) * P_{rel}$ in expression (2-21). The constant of proportionality, PD_{RTP}, is the core average power density at RTP. Expression (2-21), therefore, implies that, at any elevation z, the peak power density is limited to a maximum constant value equal to $CFQ*K(z)*PD_{RTP}$ for any core power level above 50% RTP.

For power levels of less than or equal to 50%, the power density limit is fundamentally different. Expression (2-22) says that, for the purpose of limit confirmation, the core is assumed to be at 50% RTP regardless of the actual core power level. Thus, there is no power density benefit associated with reduced power operation below 50% RTP. Whether the core is at 50% RTP or 5% RTP, the F_Q limit is the same, and the effective power density limit decreases with power level.

This dichotomy in the limits above and below 50% RTP is obviously counterintuitive. Operation at a lower power level should be a benefit, all else being equal, with a higher allowed limit on F_Q. At 0% RTP, for example, the F_Q of the core should be irrelevant. It would be reasonable to expect limit expression (2-21) to apply at all power levels, not just above 50% RTP. Limit expression (2-21) essentially represents a constant limit on power density at elevation z. The power density limit is simply $CFQ*K(z)*PD_{RTP}$. Combustion Engineering NSSS plants, in fact, employ just this kind of limit at all power levels.

The reasons why Westinghouse NSSS plants do not employ this kind of limit are historical. Reference 2, for example, states that $F_Q(z)$ is "arbitrarily limited" for ≤ 50% RTP. If this arbitrary limit had not been introduced, the F_Q limit at very low powers would have approached infinity. While there are technical reasons why this is appropriate, the originators of this limit instead chose to limit the allowable F_Q at low powers to a very high value (twice the full power value) that would likely never be exceeded. In this report, the current F_Q limit power dependence will be retained. This power dependence, however, does have implications for both the current and improved F_Q Surveillance formulations for part-power surveillances (when $P_{rel} < 1.0$). This will be discussed further in Sections 3 and 4.

When CAOC and RAOC power shape evaluations are performed to confirm that the core will meet the F_Q limit during non-equilibrium operation, individual power shapes generated using the CAOC or RAOC methodologies are compared to the limit. If necessary, the AFD operating space can be modified to ensure that limits will be met. The power shape checks performed are given by the following expressions, which are modifications of expressions (2-21) and (2-22):

$$Max\ over\ i\ \left[F_Q(z) * P_{rel}\right]_i \leq CFQ * K(z) \quad for\ P_{rel} > 0.5 \tag{2-23}$$

$$Max\ over\ i\ \left[F_Q(z) * 0.5\right]_i \leq CFQ * K(z) \quad for\ P_{rel} \leq 0.5 \tag{2-24}$$

where:

the bracketed term is the $F_Q(z) * P_{rel}$ for a given power shape i, including appropriate uncertainties.

In the current F_Q Surveillance Technical Specifications, it is necessary to meet the $F_Q(z)$ limit at both the surveillance condition (steady-state) and considering future non-equilibrium operation (transient). In both the current and improved F_Q Surveillance Technical Specifications, the steady-state $F_Q(z)$ with uncertainties is called $F_Q^C(z)$ while the transient $F_Q(z)$ is called $F_Q^W(z)$. $F_Q^C(z)$, therefore, is the $F_Q(z)$ at the surveillance condition, i.e., the actual $F_Q(z)$ for the core state at the time of the surveillance. $F_Q^W(z)$ is the maximum postulated transient $F_Q(z)$ that could potentially occur in the future during aggressive non-equilibrium operation. $F_Q^W(z)$, therefore, quantifies the maximum expected $F_Q(z)$ for a future hypothetical core state. Since future operation may occur anywhere within the allowed operating space (i.e., at any permitted power level, AFD, or control rod position within the insertion limits), the assessment of $F_Q^W(z)$ must account for a range of possible future core states. In the current F_Q Surveillance formulation, this is accomplished through the W(z) factor. In the improved F_Q Surveillance formulation for RAOC plants, this will be accomplished through a related factor called T(z).

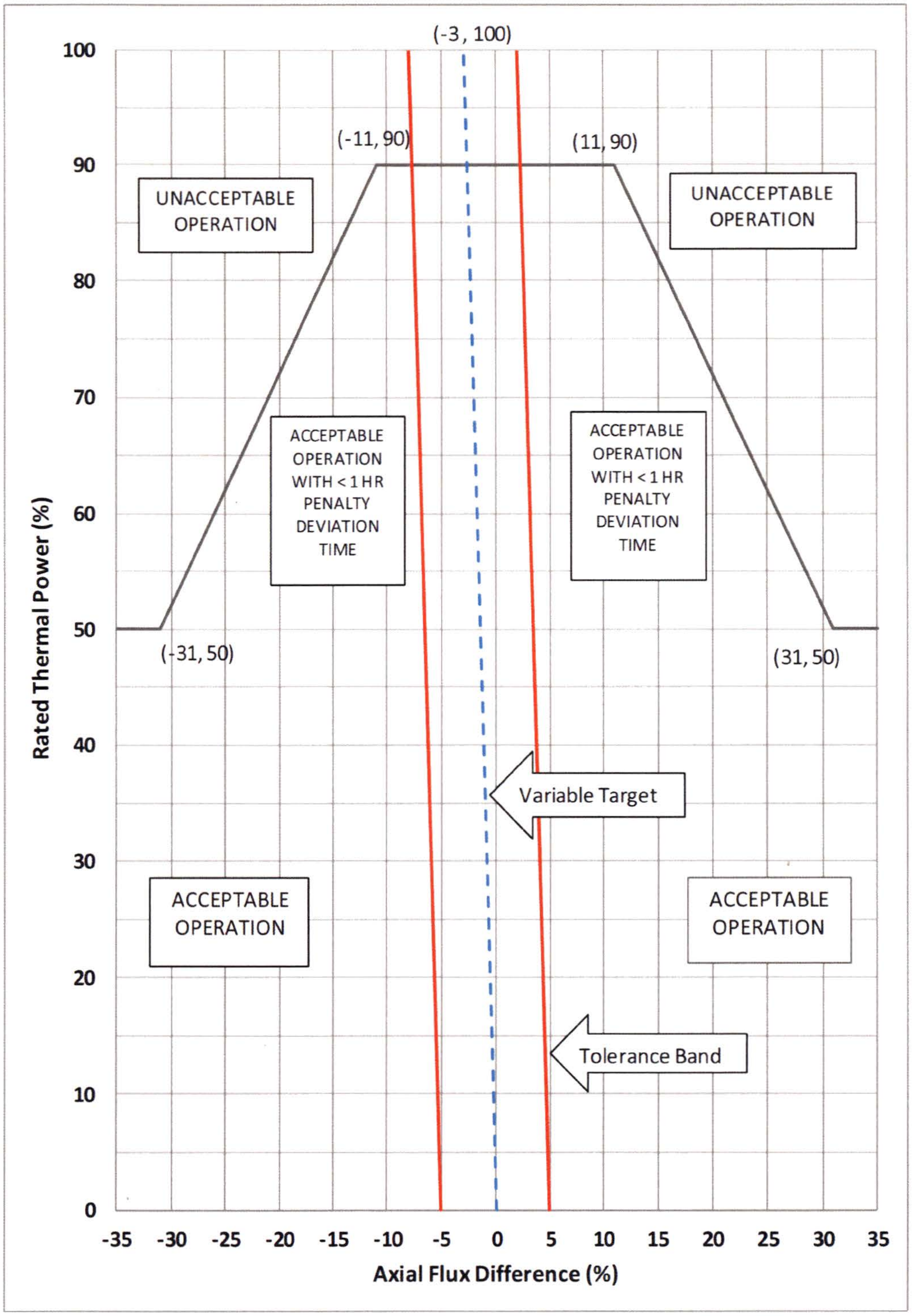

Figure 2-1 Typical CAOC AFD Target Band (±5%) and Acceptable Operation Limits

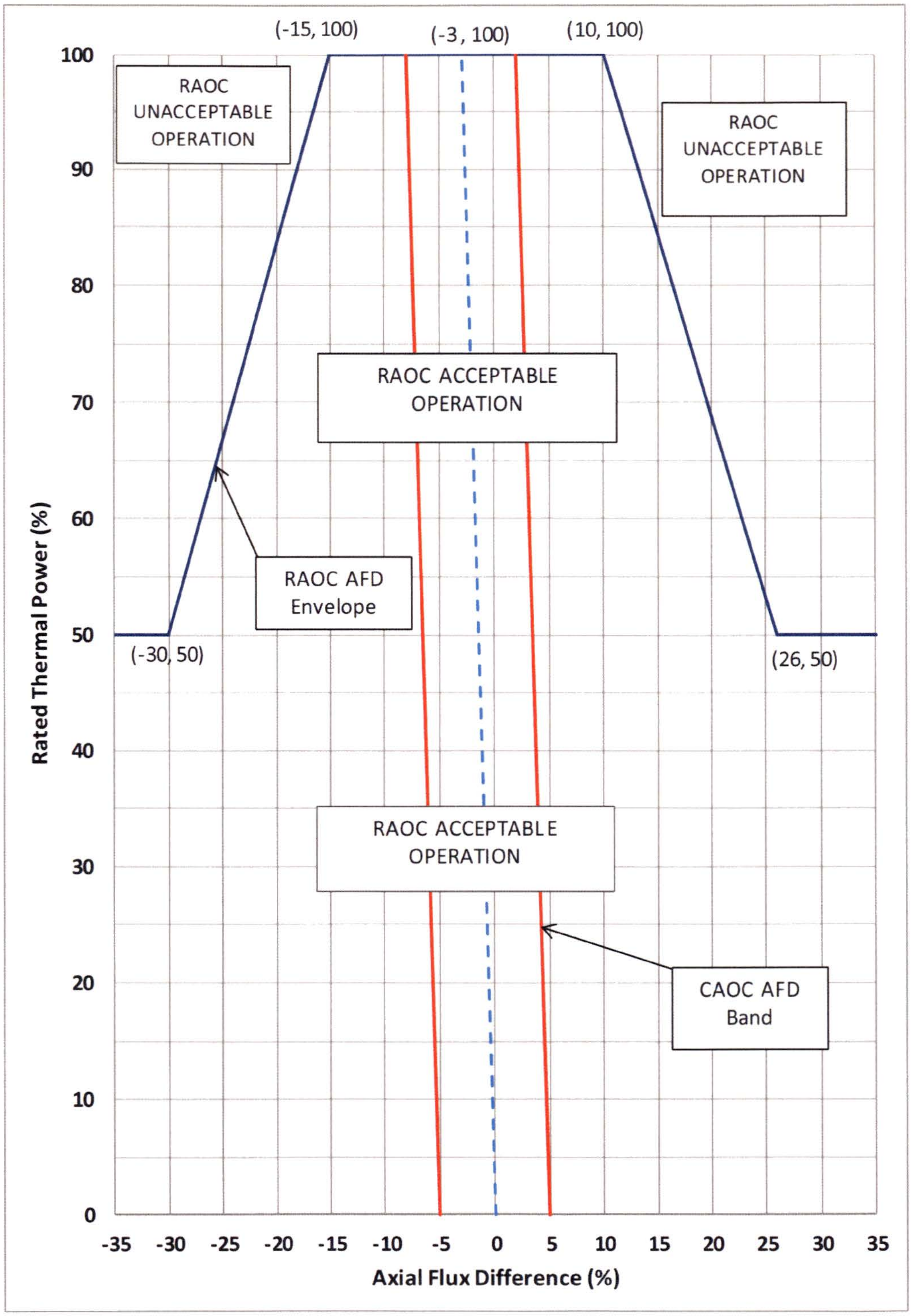

Figure 2-2 Comparison of Typical RAOC AFD Envelope and CAOC AFD Band

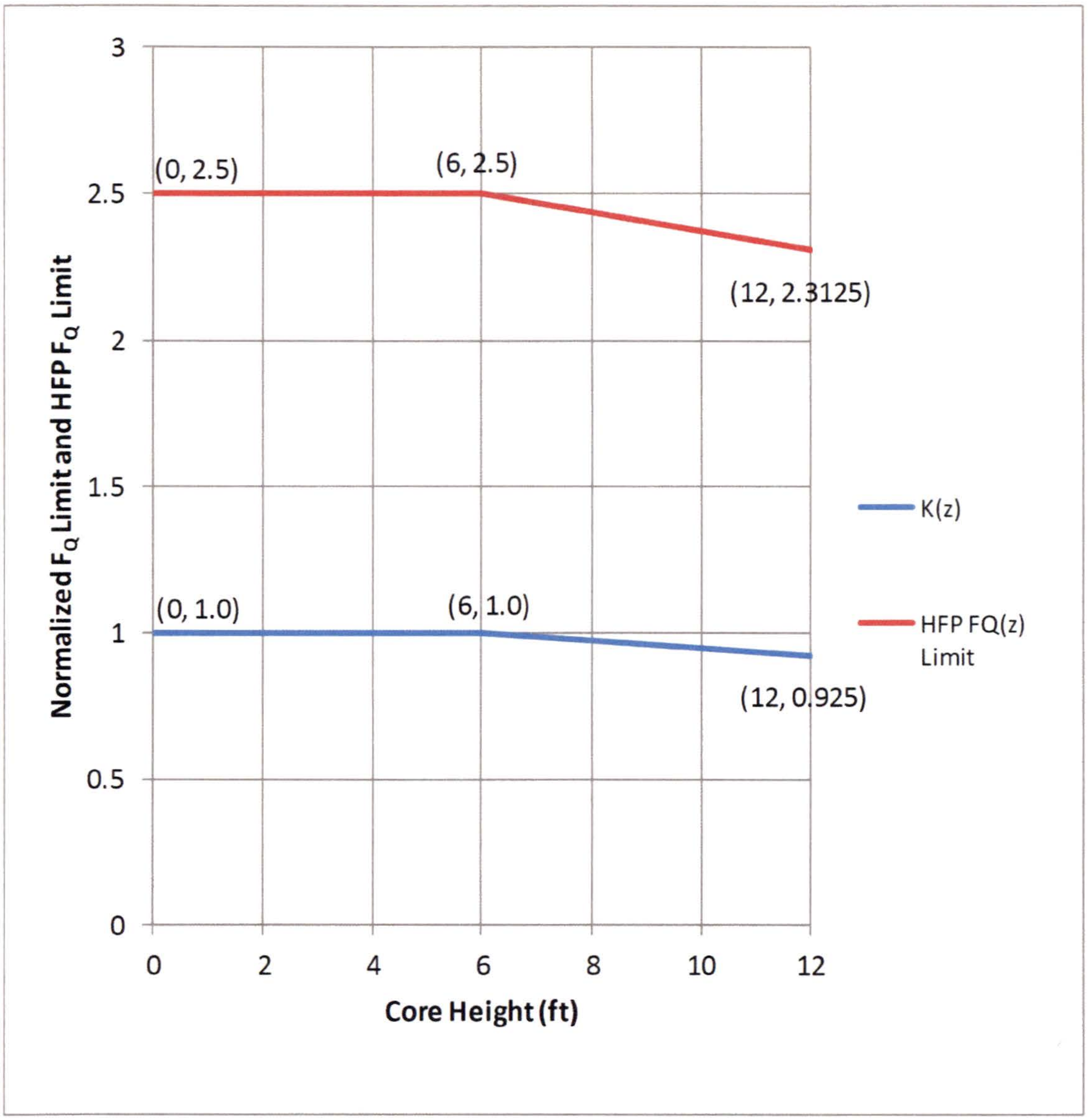

Figure 2-3 Typical Normalized and HFP FQ(z) Limits

3 CURRENT F_Q SURVEILLANCE FORMULATION AND TECHNICAL SPECIFICATIONS

In this section, the current RAOC and CAOC F_Q Surveillance Technical Specifications will be discussed and specific areas for improvement will be identified.

3.1 F_Q SURVEILLANCE MATHEMATICAL FORMULATION

Before describing the mathematical formulation for the improved F_Q Surveillance Technical Specification for RAOC plants, it is useful to review the mathematical formulation for the current F_Q Surveillance formulation as it is applied to both CAOC and RAOC plants. An objective of this discussion is to highlight areas where the current formulation requires improvement.

The power shape analysis methodologies of References 2, 3, and 4 for CAOC and Reference 5 for RAOC specify the normal operation power shapes analyses that are performed to analytically confirm that the core will meet the $F_Q(z)$ limits during non-equilibrium operation within the allowed operating space. For a given core design, these analyses result in thousands of individual power shapes representing a wide range of core power levels, xenon shapes, and control rod positions for various operating cycle average burnups. As discussed in the previous section, each individual power shape is evaluated relative to the limit. For any particular evaluated cycle burnup, there will be one power shape that results in the maximum power density (i.e., the maximum $F_Q(z)*P_{rel}$ value) at a given elevation z. That limiting shape determines the minimum margin to the limit for that cycle burnup and for that elevation. The minimum margin must be positive, i.e., the maximum $F_Q(z)*P_{rel}$ must be less than the limit. Symbolically, this power shape evaluation can be expressed as modifications of the F_Q limit expressions (2-21) and (2-22) as follows:

$$CFQ * K(z) \geq Max\ over\ i\left[F_Q^{Tr}(z) * P_{rel}\right]_i \qquad for\ P_{rel} > 0.5 \tag{3-1}$$

$$CFQ * K(z) \geq Max\ over\ i\left[F_Q^{Tr}(z) * 0.5\right]_i \qquad for\ P_{rel} \leq 0.5 \tag{3-2}$$

These are just slight rearrangements of expression (2-23) and (2-24). In these expressions, $F_Q^{Tr}(z)$ is the $F_Q(z)$ for a particular transient power shape i determined using an approved core model and the CAOC or RAOC methods. [

]^{a,c} The variable P_{rel} in these expressions is the core relative power for power shape i. If P_{rel} is greater than 0.5 (i.e., > 50% RTP), then expression (3-1) is employed. Otherwise, expression (3-2) must be used. Expression (3-1) is convenient for comparing limiting shapes (which always occur at high power levels) because each shape is essentially characterized by $F_Q^{Tr}(z)*P_{rel}$, which is proportional to the maximum power density of the shape at elevation z, and is compared to the same limit, $CFQ * K(z)$.

In the remaining portion of this description, we will work solely with (3-1). It should be understood that when an analytical power shape has P_{rel} less than 0.5, P_{rel} for the shape should be set to 0.5. Such shapes, however, are never limiting. [

]^{a,c}

Expression (3-1) expresses a desired analytical result. A key purpose of the F_Q Surveillance Technical Specification is to confirm this result, via measurement, for future non-equilibrium operation given the actual measured core peaking factors at the surveillance condition. [

]^{a,c}

[ ]^{a,c} (3-3)

]^{a,c}

Expression (3-3) can be rearranged to group the analytical terms together as follows:

[ ]^{a,c} (3-4)

It is necessary to increase the right-hand side (RHS) of the above expression by an uncertainty term of that accounts for manufacturing and measurement uncertainties. Typically, this uncertainty factor is 1.0815 when standard moveable detector flux map measurement methods are employed. Plants employing on-line power distribution monitoring systems may use a slightly different value (see WCAP-12472-P-A (Proprietary) and WCAP-12473-A (Non-Proprietary), "BEACON: Core Monitoring and Operations Support System" [Reference 12]). In either case, the uncertainty factor will be designated as U_F. With the inclusion of this term, expression (3-4) becomes:

[ ]^{a,c} (3-5)

As expression (2-19) indicates, the $F_Q(z)$ limit is an inverse function of power. If the surveillance relative power is something other than 1.0, the limit is increased by the factor $1/P_{rel}$. To put the left-hand side (LHS) of (3-5) in the form of the power dependent $F_Q(z)$ limit that is used in the current F_Q Technical Specification, both sides of expression (3-5) must be divided by the surveillance relative power, as shown:

[ ]^{a,c} (3-6)

Now the LHS of this expression is consistent with the functional form of the $F_Q(z)$ limit for core relative powers greater than 0.5.

Expression (3-6) is the fundamental transient F_Q Surveillance expression used in CAOC and RAOC plants. It should be noted that the P_{rel} terms in the ratio on the RHS of the expression are different. In the numerator, P refers to the relative powers of the analytical power shapes generated in the power shape analyses. [ ]^{a,c} In the denominator, P_{rel} refers to the steady-state (SS) surveillance relative power level at the time of the measurement and corresponds to the relative power term in the F_Q limit expression. Division by P_{rel}^{ss} is only necessary because of the functional form of the limit. If the Technical Specification were structured to have two limits—one for $F_Q^C(z)$, the steady-state peaking factor, and another for $F_Q^W(z)$, the transient peaking factor—inclusion of the $1/P_{rel}^{ss}$ factor in (3-6) would be unnecessary. The limit for $F_Q^W(z)$ could simply be CFQ*K(z). Alternatively, a single limit could be established for both steady-state and transient operation. Instead of specifying a limit on measured $F_Q(z)$, however, the single limit could be based on measured $F_Q(z)*P_{rel}$ or on measured absolute power density (as in the Combustion Engineering NSSS plants).

The RHS of expression (3-6) is $F_Q^W(z)$, the postulated maximum transient $F_Q(z)$ for non-equilibrium operation. Therefore:

[ ]^{a,c} (3-7)

The ratio in the RHS of expression (3-7) is the analytical factor W(z). Consequently,

$$F_Q^W(z) = W(z) * [F_Q(z)]_{Surv}^M * U_F \tag{3-8}$$

where:

[ ]^{a,c} (3-9)

The steady-state surveillance $F_Q(z)$ including uncertainty is defined as $F_Q^C(z)$, i.e.,:

$$F_Q^C(z) = [F_Q(z)]_{Surv}^M * U_F \tag{3-10}$$

From expressions (3-6), (3-9), and (3-10) then:

$$F_Q^W(z) = W(z) * F_Q^C(z) \leq \frac{CFQ}{P_{rel}^{ss}} * K(z) \qquad (3\text{-}11)$$

When P_{rel}^{SS} is 0.5 or less, the following expressions apply:

[ ]^{a,c} (3-12)

$$F_Q^W(z) = W(z) * F_Q^C(z) \leq \frac{CFQ}{0.5} * K(z) \qquad (3\text{-}13)$$

Together, expressions (3-9) through (3-13) compose the basic F_Q Surveillance mathematical formulation for both RAOC and CAOC plants for all surveillance power levels. The W(z) factor quantifies the postulated increase in power density due to non-equilibrium operation relative to the surveillance core state; it essentially scales the measured steady-state $F_Q(z)$ by the maximum postulated increase in $F_Q(z)*P_{rel}$ relative to the equilibrium value. Recall that the P_{rel}^{ss} term in the expression for W(z) serves only to normalize the result to the applicable $F_Q(z)$ limit at the surveillance power level. (Since this term appears on both sides of the inequality in (3-11), it could be canceled out with no mathematical consequence. The same, of course, is true for the 0.5 factor in expression (3-13)).

Determination of the W(z) factors using expression (3-9) is reasonably straightforward. To generate them, however, it is necessary to make a key assumption, i.e., some reference surveillance condition must be assumed. [

]^{a,c}

Typically, the surveillance condition assumed in calculating the W(z) factors for the COLR is HFP, all rods out (ARO), and equilibrium xenon (EQXE). Effectively, this is the "reference core condition" for the W(z) factors. When this reference condition is assumed, the COLR W(z) values are given by the following:

[ ]^{a,c} (3-14)

where:

$[F_Q(z)]_{Ref}^{P}$ is the predicted steady-state $F_Q(z)$ at the reference core condition, typically HFP, ARO, EQXE.

When the COLR W(z) values are employed for a given surveillance, they are divided by the surveillance power level or 0.5 to ensure consistency with the F_Q limit at that power level. That is:

$$W(z) = \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} \quad for\ P_{rel}^{ss} > 0.5 \tag{3-15}$$

$$W(z) = \frac{[W(z)]^{COLR}}{0.5} \quad for\ P_{rel}^{ss} \leq 0.5 \tag{3-16}$$

Strictly speaking, the above expressions are only true when the predicted $F_Q(z)$ at the true surveillance condition and the predicted $F_Q(z)$ at the reference condition assumed for $[W(z)]^{COLR}$ are the same, i.e., when $[F_Q(z)]_{Surv}^{P}$ in (3-9) is equal to $[F_Q(z)]_{Ref}^{P}$ in (3-14). Generally, use of HFP, ARO, EQXE as the reference core condition is a good assumption since the vast majority of surveillances are performed at or very near this core state. However, during the startup of a new operating cycle, surveillances are frequently performed at power levels as low as ~30% RTP. Also, it occasionally becomes necessary to perform a mid-cycle part-power surveillance.

Suppose that a beginning of life (BOL) surveillance is performed at 30% RTP, but the reference condition assumed in generating the W(z) factors for the COLR was HFP, ARO, EQXE. It is trivial to adjust the W(z) factors to account for the core relative power difference. This is simply a matter of dividing the HFP W(z) factors in the COLR by the surveillance relative power if $P_{rel}^{ss} > 0.5$ or by 0.5 if $P_{rel}^{ss} \leq 0.5$. As mentioned above, this factor only serves to scale W(z) and $F_Q^W(z)$ for consistency with the F_Q limit at the part power condition. It is not as trivial, however, to account for differences between $[F_Q(z)]_{\mathrm{Surv}}^{P}$ and $[F_Q(z)]_{\mathrm{Ref}}^{P}$ unless the surveillance core state is known in advance. [

]^{a,c}

To better understand the nature of these inaccuracies and their implications for RAOC and CAOC plants, it is useful to expand the $F_Q(z)$ terms in expression (3-6) using the F_Q synthesis expression (2-10) as follows:

[ ]^{a,c} (3-17)

Now, suppose we consider only the limiting predicted power shape that results in the minimum margin to the F_Q limit, which occurs at some elevation z_0. Then:

[ ]^{a,c} (3-18)

This expression can be rearranged by re-grouping terms as follows:

[ ]^{a,c} (3-19)

In an actual surveillance, the W(z) values used will be the $[W(z)]^{COLR}$ values included in the COLR. These values assume some reference condition, usually HFP, ARO, EQXE. In this case, the $[F_{XY}(z_0)]^{P}_{Surv}$ and $[P(z_0)]^{P}_{Surv}$ terms in expression (3-19) will correspond to $[F_{XY}(z_0)]^{P}_{Ref}$ and $[P(z_0)]^{P}_{Ref}$. Expression (3-19) then becomes:

[ ]^{a,c} (3-20)

Each of the groups of terms in expression (3-20) will now be briefly discussed.

The LHS of this inequality is simply the F_Q limit at z_0 scaled by $1/P_{rel}^{ss}$. If the surveillance power level, P_{rel}^{ss}, is 1.0, then the F_Q limit is simply the limit at full power. When P_{rel}^{ss} is greater than 0.5 but less than 1.0, the limit is scaled by $1/P_{rel}^{ss}$, effectively resulting in a constant power density limit for a given elevation. If P_{rel}^{ss} is less than or equal to 0.5, then P_{rel}^{ss} is set to 0.5 in expression (3-20), effectively increasing the F_Q limit by a factor of 2 for relative powers less than or equal to 0.5.

The first bracketed expression on the RHS of expression (3-20) is the analytically determined transient F_Q*Power value at the limiting axial location and for the limiting RAOC/CAOC power shape, i.e., the power shape that produced the minimum margin to the limit. Because the F_Q limit increases dramatically with reduced core power level, the limiting margin power shape is virtually always a power shape occurring at HFP, i.e., a power shape where P_{rel} is 1.0.

The next term on the RHS of expression (3-20) is the reciprocal of the surveillance relative power level. When the surveillance relative power is less than or equal to 0.5, then this ratio is equal to 1/0.5 or 2. Otherwise, it is equal to $1/P_{rel}^{ss}$. As discussed earlier, this term simply scales the transient F_Q*Power value to be consistent with the F_Q limit at the surveillance power level. This term could be cancelled from both sides of the expression with no mathematical consequence, i.e., no change in the transient F_Q margin assessment.

[ ]^{a,c}

[ ]^{a,c} As discussed earlier, radial peaking factors are largely determined by the core loading pattern. While radial peaking factors are not highly sensitive to power level, there is, however, some power level dependence through changes in local Doppler and moderator reactivity feedback with core power. Also, changes in equilibrium xenon number densities with power level can influence radial peaking factors. These feedback effects tend to flatten the radial power distribution at high core power levels since high power core locations will experience larger negative reactivity feedback than lower power locations. When reactor power is decreased, the opposite trend occurs, i.e., slightly larger radial peaking factors can result. Tables 3-1 and 3-2 illustrate this sensitivity.

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]a,c

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The deepest rod insertion for a surveillance typically occurs during the first flux map following a refueling. The primary purpose of this flux map is to confirm that the core is loaded properly. This measurement is typically performed between 25% and 50% RTP. Because of the low power level, the lead control bank is usually inserted to maintain the AFD near the expected natural target value. Consequently, both rodded operation and part power operation can affect the measured radial peaking factors and the F_Q margin assessment for this measurement. Table 3-4 compares the $F_{XY}(z)$ values used as the basis for generating COLR W(z) values at BOL, HFP with the expected $F_{XY}(z)$ values for an initial flux map following a refueling. The core state for the flux map was 26.4% RTP with D-Bank at 176 steps withdrawn (i.e., inserted about 2.5 ft into the top of the active core). The increases in the F_{XY} values due to the reduced power core condition and control rod insertion are clearly evident. [

]^{a,c}

It is important to note that the transient radial peaking factor effects caused by rodded operation and part power operation are analytically accounted for in the RAOC and CAOC power shape analyses. For a given power shape, the $F_{XY}^{Tr}(z)$ term in (3-17) accounts for the increases in F_{XY} that occur because of transient operation at reduced power or control rod insertion. Usually, however, F_Q margin is limiting for full power shapes. Also, while rodded power shapes may be limiting in the power shape analysis, it is the unrodded radial planes of those power shapes that are limiting with respect to F_Q margin.

The preceding discussion detailed the radial peaking factor sensitivity of the transient F_Q margin assessment caused by the disparity between the actual surveillance condition and the reference condition assumed in generating the COLR W(z) factors. [

]^{a,c} This is the ratio of the measured and predicted core average axial power shapes. The measured axial power shape in this ratio is simply the core average measured axial shape determined during the surveillance. The predicted axial power shape is the core average power shape for the reference surveillance condition assumed in the generation of the COLR W(z) factors.

Ideally, this ratio is equal to 1.0, i.e., the measured and predicted axial power shapes at the surveillance condition exactly agree. Just as there can be radial tilts, however, there can be axial tilts such that the measured and predicted power shapes may not exactly agree. Such a difference can be characterized by the AO difference between the axial shapes, commonly called the Delta-AO (ΔAO). ΔAO is defined as the measured minus predicted axial offset. [

]^{a,c}

For CAOC cores, this deviation is not problematic with respect to the accuracy of the surveillance. In fact, it is necessary to capture this effect in the F_Q Surveillance formulation for CAOC. The current formulation does this reasonably well. As discussed in Section 2, the permitted AFD variation about the target AFD is fixed in CAOC operation. Thus, the AFD may be permitted to vary, for example, ±5% relative to the target. [

]^{a,c}

This is illustrated in Figure 3-1. Figure 3-1 shows two baseload (BL) $F_Q(z)$ shapes which differ due to an imposed ΔAO. The first shape, labeled BL1, is the $F_Q(z)$ shape corresponding to an axial offset of +0.5%, a reasonably typical value for BOL. For discussion purposes, this will be assumed to be the predicted steady-state $F_Q(z)$. The second shape, labeled BL2, is the $F_Q(z)$ shape corresponding to an axial offset of -2.5%, a ΔAO of -3% relative to BL1. For discussion purposes, this will be assumed to be the measured steady-state $F_Q(z)$. This shape was generated by slightly modifying the axial burnup distribution of the core model used to generate shape BL1. Transient $F_Q(z)$ shapes were then created from each of these baseload shapes by imposing "transient" axial xenon shapes to skew the AO of each power shape ~5% more negative. This 5% AO difference corresponds to a maximum negative AFD deviation permitted at HFP for a CAOC AFD band of ±5%. These shapes are labeled CAOC1 and CAOC2 in Figure 3-1. CAOC1, therefore, is the predicted transient shape while CAOC2 would be the expected measured transient shape.

Figure 3-1 clearly shows that, as expected, the maximum $F_Q(z)$ values for the transient shapes are different. The maximum F_Q value for CAOC2 is larger than for CAOC1. This is simply because each transient shape was skewed 5% more negative than its corresponding baseload shape, but BL2 was already skewed 3% more negative than BL1. Consequently, CAOC2 is more skewed than CAOC1 and has a correspondingly larger maximum F_Q. [

]^{a,c}

Figure 3-2 plots these ratios.

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]^{a,c}

The situation is very different for RAOC plants. To illustrate this, a similar power shape exercise was performed except that AFD assumptions appropriate for RAOC were employed. Figure 3-3 shows the same two baseload shapes as in Figure 3-1. Figure 3-3 also shows two RAOC transient $F_Q(z)$ shapes labeled RAOC1 and RAOC2. For RAOC1, the BL1 shape was skewed to a HFP AFD limit of -15% using a transient xenon distribution. Similarly, the BL2 shape was skewed to the same -15% AFD limit to generate RAOC2. This is appropriate since, for RAOC, the AFD operating space is fixed and is not a function of the natural target AFD. The -15% AFD value at HFP represents the most negative AFD value permitted at HFP irrespective of the AFD of the baseload shape.

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]^{a,c}

To further illustrate this point, Figure 3-4 compares rigorously calculated worst case transient axial power shape results for a RAOC plant with a fixed AFD band of -15% to +10% at HFP using models which simulate effects producing strongly skewed steady state axial power distributions. [

]^{a,c}

From this discussion, we can conclude the following with respect to the sensitivity of the F_Q Surveillance formulation to differences between the measured and predicted surveillance power shapes:

[

]^{a,c} Consequently, for CAOC plants, the current F_Q Surveillance formulation works reasonably well.

[

]^{a,c} The improved F_Q Surveillance formulation for RAOC plants is discussed in Section 4.

3.2 CURRENT HEAT FLUX HOT CHANNEL FACTOR TECHNICAL SPECIFICATIONS FOR RAOC AND CAOC PLANTS

The above discussion details the current F_Q Surveillance mathematical formulation and its issues, especially with respect to RAOC plants. In the remainder of Section 3, the current RAOC and CAOC Heat Flux Hot Channel Factor Technical Specifications will be discussed and areas for improvement will be identified.

3.2.1 Limiting Condition for Operation

The Limiting Condition for Operation (LCO) for both the RAOC and CAOC versions of the TS is the same and specifies that $F_Q(z)$, as approximated by $F_Q^C(z)$ and $F_Q^W(z)$, shall be within the limits specified in the COLR. As discussed in Section 3.1, $F_Q^C(z)$ is the equilibrium $F_Q(z)$ at the surveillance condition, while $F_Q^W(z)$ is the transient $F_Q(z)$ for future non-equilibrium operation within the allowed operating space. $F_Q^C(z)$ and $F_Q^W(z)$ are compared to the same limit, which is a function of power level and is specified in the COLR. This LCO is unchanged in the improved versions of the F_Q Technical Specifications.

3.2.2 Required Actions for Condition A: $F_Q^C(z)$ not within Limit

When $F_Q^C(z)$ exceeds the limit, the core is in an unanalyzed state following the performance of Surveillance Requirement (SR) 3.2.1.1 in that the current peak power density in the core is greater than the maximum value assumed in the safety analyses. Both the CAOC and RAOC versions of the TS have the same Required Actions and Completion Times for Condition A, "$F_Q^C(z)$ not within limit." When $F_Q^C(z)$ is not within its limit, it is required to: (1) Reduce thermal power $\geq$ 1% RTP within 15 minutes for each 1% $F_Q^C(z)$ exceeds the limit (Required Action A.1), (2) Reduce the Power Range Neutron Flux – High trip setpoint by $\geq$ 1% within 72 hours for each 1% $F_Q^C(z)$ exceeds the limit (Required Action A.2), (3) Reduce the Overpower ΔT trip setpoints by $\geq$ 1% within 72 hours for each 1% $F_Q^C(z)$ exceeds the limit (Required Action A.3), and (4) Perform surveillances on $F_Q^C(z)$ and $F_Q^W(z)$ prior to increasing the thermal power above the limit of the Required Action A.1 (Required Action A.4).

In principle, these actions remain appropriate and will be retained in the improved F_Q Technical Specifications. However, the wording in Required Actions A.3 and A.4 which specifies the magnitude of the setpoint reductions will be modified to account for the possibility that the limit for $F_Q^C(z)$ is exceeded during a part-power surveillance. When the limit for $F_Q^C(z)$ is exceeded, thermal power will be limited to less than the surveillance power level by Required Action A.1. The corresponding setpoint reductions should therefore reflect this new thermal power limit. These Required Actions will state that the setpoints must be reduced by ≥ 1% for each 1% that the thermal power is limited below the RTP by Required Action A.1. For example, if the surveillance thermal power is 75% and $F_Q^C(z)$ exceeds its limit by 1%, thermal power will be limited to ≤ 74% RTP. Consequently, the new wording will require setpoint reductions of ≥ 26% since this is the amount by which the thermal power is limited below the RTP. The current Required Action wording would only require a setpoint reduction of ≥ 1%. Strictly speaking, the current wording is only appropriate if the surveillance is performed at full power.

Two points, however, are worth noting on this. First, the likelihood of $F_Q^C(z)$ ever exceeding its limit is extremely small, especially at reduced power levels. Typically, steady-state peak F_Q values are 20% to 40% less than the limit. As such, a massive core anomaly would be required for the limit to be exceeded. Such a core anomaly would almost certainly be due to a fuel misload and would in all likelihood be detected during the first power distribution measurement following a refueling, the primary purpose of which is to confirm that the core is loaded properly. Continued operation at elevated power levels in the presence of such an enormous anomaly would need to be evaluated.

The second point is that, if $F_Q^C(z)$ exceeds its limit, then $F_Q^W(z)$ will exceed its limit by an even greater amount since $F_Q^W(z)=W(z)*F_Q^C(z)$ and W(z) is always greater than 1.0 (sometimes much larger than 1.0) for the surveilled portion of the core. As such, the Required Actions when Condition A is entered may actually be less limiting than the Required Actions for Condition B, "$F_Q^W(z)$ not within limits."

3.2.3 Required Actions for Condition B: $F_Q^W(z)$ not within Limit

The Required Actions for Condition B are different for RAOC and CAOC. Both will be revised in the improved F_Q Technical Specifications.

Current Condition B Required Actions for CAOC

For CAOC, the current Required Actions for Condition B are the same as for Condition A except that the basis for the reduction in the thermal power and the trip setpoints is the magnitude by which $F_Q^W(z)$ exceeds its limit instead of the magnitude by which $F_Q^C(z)$ exceeds its limit.

When $F_Q^W(z)$ exceeds the limit and $F_Q^C(z)$ does not, the actual peak power density in the core following performance of the Surveillance (SR 3.2.1.2) still meets the $F_Q(z)$ limit; however, future non-equilibrium operation (e.g., load follow) could potentially produce power shapes that exceed the $F_Q(z)$ limit. From Reference 1, Required Action B.1 states the following: "Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(z)$ exceeds limit." This Required Action is actually overly restrictive. For example, suppose a surveillance performed at 30% RTP following a refueling indicates that $F_Q^W(z)$ could exceed its limit by 1% for future non-equilibrium operation. Required Action B.1 would require a reduction in the current thermal power from 30% RTP to ≤ 29% RTP. The problem with this is that 30% RTP is a non-limiting power level. For CAOC (and typically for RAOC as well), the full power transient power shapes are

limiting and determine the W(z) values and the limiting $F_Q^W(z)$ margin values. A more appropriate Required Action would be to limit thermal power to ≤ 99% RTP, i.e., reduce the maximum allowable power level by ≥ 1% RTP for each 1% that $F_Q^W(z)$ exceeds its limit.

The improved CAOC F_Q Technical Specification will be discussed in more detail in a later section. Briefly, this action is replaced by a new Required Action B.1 that requires implementation of a new CAOC operating space, specified in the COLR, which restores $F_Q^W(z)$ to within its limits. A CAOC operating space is a unique combination of CAOC AFD band limits and control bank insertion limits. A more restrictive CAOC operating space limits the range of possible non-equilibrium power shapes more than the current CAOC operating space through a smaller AFD band and/or shallower control bank insertion limits. The smaller CAOC operating space results in more transient F_Q margin. The margin difference between two CAOC operating spaces at a given core elevation is characterized by the ratio of their respective W(z) functions at that elevation. If, for example, $F_Q^W(z)$ exceeds its limit by 1% at an elevation of 5 feet for the current CAOC operating space, a CAOC operating space included in the COLR with a W(z) value at 5 feet that is at least 1% less than the W(z) for the current operating space would provide the required margin to demonstrate that the LCO is met. Alternatively, instead of implementing a more restrictive CAOC operating space, thermal power may be limited to some maximum value as specified in the COLR.

Current Condition B Required Actions for RAOC

For RAOC, current Required Action B.1 requires the following action within 4 hours when $F_Q^W(z)$ is not within its limits: "Reduce AFD limits ≥ 1% for each 1% $F_Q^W(z)$ exceeds limit." Therefore, when the F_Q limit is exceeded, the AFD operating space is made more restrictive on both the positive and negative sides to limit the range of non-equilibrium power shapes that can occur during future operation. If the reduction in the AFD envelope is large enough such that operation at Rated Thermal Power is not possible, then the maximum allowable power level must be reduced. In this case, current Required Actions B.2 and B.3 require corresponding reductions in the Power Range Neutron Flux–High and Overpower ΔT trip setpoints within 72 hours, and Required Action B.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing thermal power above the maximum allowable power of the AFD limits.

While reductions in the AFD envelope will usually reduce the expected maximum values of $F_Q^W(z)$, the magnitude of this benefit is very dependent on the axial location of the minimum $F_Q^W(z)$ margin. The presumption is that, if W(z) values were available for the reduced AFD envelope, a surveillance using those W(z) factors would demonstrate that the LCO would be met. [

]^{a,c}

Figure 3-6 illustrates this problem. This figure shows the ratio of RAOC W(z) values at a cycle burnup of 4000 MWD/MTU generated for two different AFD operating spaces, one with a (-15%, +10%) range at HFP and the other with a (-10%, +5%) range at HFP (see Figure 6-1 for the AFD operating spaces

assumed). The second AFD operating space represents, therefore, a 5% AFD reduction relative to the first. This is the kind of reduction that Required Action B.1 would specify if the F_Q limit were exceeded by 5%. [

]^{a,c}

The improved F_Q Technical Specification will specify Required Actions for RAOC operation that will be sufficient to ensure that peak power densities will remain within the bounds of the safety analysis assumptions in the unlikely event that $F_Q^W(z)$ exceeds the limit. Pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be included in the COLR and characterized by transient factors (T(z) functions) which, in conjunction with measured radial peaking factors, may be used to quantify margin and ensure compliance with the LCO for future non-equilibrium operation. Analogous to the CAOC operating space concept described earlier, a RAOC operating space is a unique combination of an AFD operating space envelope and control bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient transient F_Q margin, maximum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the required reductions will be included in the COLR. This is discussed in more detail in Section 5.3.

3.2.4 Current Surveillance Requirements for $F_Q^C(z)$: SR 3.2.1.1

The current Surveillance Requirements for $F_Q^C(z)$ are the same for both the CAOC and RAOC versions of the current F_Q Technical Specification. SR 3.2.1.1 requires verification that $F_Q^C(z)$ is within its limit. The current Frequencies for SR 3.2.1.1 specify that $F_Q^C(z)$ must be verified to be within its limit:

a. Once after each refueling prior to THERMAL POWER exceeding 75% RTP; and

b. Once within 12 hours after achieving equilibrium conditions after exceeding, by $\geq$ 10% RTP, the THERMAL POWER at which $F_Q^C(z)$ was last verified; and

c. Each 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

These Frequencies would permit power escalation following a refueling to no more than 75% RTP prior to performance of the first verification of $F_Q^C(z)$. Together, these three Frequencies are unambiguous and appropriately verify $F_Q^C(z)$ during the initial power escalation and throughout the operating cycle. They will be retained in the improved F_Q TS with one minor change. In the improved F_Q TS, the second Frequency will be revised to require verification of $F_Q^C(z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by $\geq$ 10% RTP, the THERMAL POWER at which

$F_Q^C(z)$ was last verified. This Frequency of 24 hours is contained in some plant Technical Specifications. (for a few plants, no Frequency is specified) and is a reasonable time period in which to perform this verification given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

SR 3.2.1.1 is modified by a note. The note also applies to SR 3.2.1.2, which is the Surveillance Requirement for $F_Q^W(z)$. The note states the following:

"During power escalation at the beginning of each cycle, thermal power may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."

This note has been a source of confusion and is interpreted differently by various utilities. Some interpret this note to mean that, if multiple flux maps are taken prior to achieving 75% RTP following a refueling, then $F_Q^C(z)$ and $F_Q^W(z)$ must be verified to be within limits for each flux map. Other utilities interpret the note and the SR to require only a single verification of $F_Q^C(z)$ and $F_Q^W(z)$ during the power escalation following a refueling, as long as that verification is obtained prior to exceeding 75% RTP.

In the improved F_Q TS, this note will simply be eliminated. As stated earlier, the surveillance Frequencies for $F_Q^C(z)$ are unambiguous. It is sufficient to confirm $F_Q^C(z)$ once prior to exceeding 75% RTP following a refueling. When a higher power level is achieved, e.g., 100 % RTP, the TS requires another verification of $F_Q^C(z)$. Thus, $F_Q^C(z)$ will continue to be confirmed at high power levels where margin will be at its minimum. In the unlikely event that the limit for $F_Q^C(z)$ is exceeded, the Required Actions will specify compensatory power and setpoint reductions.

3.2.5 Current Surveillance Requirements for $F_Q^W(z)$: SR 3.2.1.2

The current Surveillance Requirements for $F_Q^W(z)$ are the same for both the CAOC and RAOC versions of the current F_Q Technical Specification. SR 3.2.1.2 requires verification that $F_Q^W(z)$ is within its limit. The current Frequencies for SR 3.2.1.2 specify that $F_Q^W(z)$ must be verified to be within its limit:

a. Once after each refueling prior to THERMAL POWER exceeding 75% RTP; and

b. Once within 12 hours after achieving equilibrium conditions after exceeding, by $\geq$ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified; and

c. Each 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

These are the same basic Frequencies as for $F_Q^C(z)$.

There are two areas for improvement in SR 3.2.1.2. The first area for improvement concerns the surveillance Frequencies.

The intent of SR 3.2.1.2 is to confirm that the F_Q limit will be met during future non-equilibrium operation within the allowed operating space between the time of the current surveillance and the next required surveillance (usually in 31 EFPD). The above Frequencies will be retained but will be slightly modified.

The first Frequency for SR 3.2.1.2 will be changed to state that $F_Q^W(z)$ must be verified to be within its limit following each refueling within 24 hours after thermal power exceeds 75% RTP. Some plant Technical Specifications have this Frequency in their TS (specifying 12 hours instead of 24 hours). This change is justified since core power distribution measurements taken at low powers (<50% RTP) to confirm that the core is loaded properly will provide ample indication that the core is operating consistent with expectations. The new Frequency will ensure that verification of $F_Q^W(z)$ is performed within a reasonable time period and prior to extended operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged. Power levels of ≤ 75% RTP are non-limiting for minimum transient $F_Q^W(z)$ margin. Furthermore, as discussed in the previous section, surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75% power ensures that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium operation could be limiting. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

The second Frequency will be modified in the same ways as SR 3.2.1.1. In the improved F_Q TS, it will require verification of $F_Q^W(z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified. As with SR 3.2.1.1, this Frequency of 24 hours is contained in some plant Technical Specifications. The Frequency of 24 hours is a reasonable time period in which to confirm that $F_Q^W(z)$ is within its limits given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The second area for improvement of SR 3.2.1.2 concerns the note modifying SR 3.2.1.2. This note states the following:

"If measurements indicate that the maximum over z [$F_Q^C(z)$ / K(z)] has increased since the previous evaluation of $F_Q^C(z)$:

a. Increase F_Q^W (z) by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(z)$ is within limits or

b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(z)$ / K(z)] has not increased."

The intent of this note in the current F_Q TS is to account for potential increases in $F_Q^W(z)$ between surveillances. It requires application of the greater of a 1.02 factor or a factor specified in the COLR (see Reference 5) whenever measurements indicate that the maximum value of $F_Q^C(z)/K(z)$ has increased. Alternatively, SR 3.2.1.2 must be repeated once per 7 EFPD until $F_Q^W(z)$ is within limits with the penalty factor applied or two successive flux maps indicate that $F_Q^C(z)/K(z)$ has not increased.

In the improved F_Q TS, this note will be eliminated, but application of a penalty factor will continue to be required whenever the <u>minimum margin</u> to the $F_Q^W(z)$ limit is <u>predicted</u> to decrease. The required penalty factors, referred to as R_j factors in this report, will be included in the COLR and will simply become part of the $F_Q^W(z)$ formulation (see discussion in Section 5.5). The penalty factors will be tied to a predicted

decrease in the actual transient F_Q margin in the upcoming time period (i.e., the next 31 EFPD) rather than a measured increase in the value of $F_Q^C(z)/K(z)$ over the previous time period. When margin is predicted to increase, the COLR will indicate an R_j factor of 1.0 (i.e., no penalty). When margin is predicted to decrease, the COLR will indicate an appropriate R_j factor based on predicted margin trends.

This is more appropriate and rigorous than the current method since decreases in margin in the upcoming time period are the relevant concern. The basis for the current SR is that past measurement trends of $F_Q^C(z)/K(z)$ can be used to determine whether or not the transient F_Q margin will decrease in the future and, therefore, whether or not a penalty factor is needed. Past measurement trends of $F_Q^C(z)/K(z)$, however, may or may not be indicative of future margin trends. Though not likely, it is conceivable for the maximum value of $F_Q^C(z)/K(z)$ to be decreasing while margin is also decreasing since margin depends not only on the maximum value of $F_Q^C(z)/K(z)$, which characterizes steady state peaking factors, but also on the range of possible non-equilibrium axial power shapes, characterized analytically by W(z) and T(z). Furthermore, the R_j penalty factors tend to be largest at BOL when the burnable absorbers are depleting relatively quickly with consequent changes in the power distribution. Current core models predict burnable absorber depletion and the resulting power distribution changes well. Thus, consistency between the measured and predicted trends in steady state peaking factors is expected. Consequently, basing the application and magnitude of the penalty factor on predicted margin trends is a reasonable approach.

Another difficulty with the current SR is that a minimum penalty of 2% is applied regardless of how small the increase in $F_Q^C(z)/K(z)$ was measured to be. Even a small increase in $F_Q^C(z)/K(z)$ of 0.1% would require a 2% penalty to be applied. The improved SR eliminates this problem since the magnitude of the penalty factor is based on the predicted margin trends; no minimum penalty is specified.

Finally, the improved SR avoids any lag in the application of the penalty factor caused by the current requirement for two successive measurements, which could be a month apart, to indicate a potential decrease in margin. These measurements characterize the margin trend in the time period that has just ended. Therefore, the improved SR will better capture the expected trend of the margin based on predictions. By eliminating the note, however, the option to perform more frequent surveillances in lieu of applying the penalty factor is also eliminated. It will be necessary to demonstrate that the LCO is met with the COLR R_j factor applied. If the LCO is not met, then the Required Actions must be implemented to restore margin.

Table 3-1 BOL, ARO, $F_{XY}(z)$ Values by Core Power Level

a,c

Table 3-2 EOL, ARO, $F_{XY}(z)$ Values by Core Power Level

a,c

Table 3-3 ARO and Lead Control Bank (Bank D) Inserted (D-In) $F_{XY}(z)$ Values at HFP at BOL and EOL

a,c

[ ]

Table 3-4 Comparison of Reference and Startup $F_{XY}(z)$ Values at BOL

a,c

Note:

1. Core planes at ~9.5 ft and above are rodded and are indicated by italics.

a,c

Figure 3-1 CAOC Baseload and Transient Shapes

a,c

Figure 3-2 Ratio of Transient and Baseload $F_Q(z)$ for CAOC $F_Q(z)$ Shapes

a,c

Figure 3-3 RAOC Baseload and Transient Shapes

a,c

Figure 3-4 Maximum Calculated Transient P(z) for a RAOC Plant Assuming Three Different Steady State Axial Offset Measurements

a,c

Figure 3-5 Ratio of Transient and Baseload $F_Q(z)$ for RAOC $F_Q(z)$ Shapes

a,c

Figure 3-6 Ratio of RAOC W(z) Values for (-15,+10) and (-10,+5) AFD Envelopes at 4000 MWD/MTU Cycle Burnup

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4 IMPROVED RAOC F_Q SURVEILLANCE FORMULATION

The previous section discussed the difficulties with the current F_Q Surveillance formulation and Technical Specification. For RAOC plants, these difficulties are especially problematic. In this section, an improved F_Q Surveillance formulation for RAOC plants will be derived that mitigates the sensitivity of the formulation to differences between measured and predicted power shapes. The methodology necessary to support this formulation will be presented.

4.1 DERIVATION OF THE IMPROVED RAOC F_Q SURVEILLANCE FORMULATION

In the absence of continuous $F_Q(z)$ monitoring, it is necessary to estimate the transient F_Q margin based on steady-state peaking factor measurements augmented by analytical factors that characterize the expected transient behavior of the core for postulated non-equilibrium operation. This is the basic philosophy of the current F_Q Surveillance formulation, and this philosophy is still necessary in the improved formulation. [

]^{a,c}

For the derivation, we start with the desired analytical result of the RAOC analysis, introduced in Section 3.1 as expression (3-1) and repeated here:

$$CFQ * K(z) \geq Max\ over\ i\ \left[F_Q^{Tr}(z) * P_{rel}\right]_i \qquad P_{rel} \geq 0.5 \tag{4-1}$$

In expression (4-1), CFQ*K(z) is the HFP F_Q limit as a function of height, $F_Q^{Tr}(z)$ is the predicted transient $F_Q(z)$ for a given core power shape i determined at a given cycle burnup, and P_{rel} is the core relative power associated with the core power shape. [

]^{a,c} Thus, in expression (4-1) we seek the maximum value of $F_Q^{Tr}(z)*P_{rel}$ at each elevation over all the power shapes generated at a given cycle burnup.

Using expression (2-10), we can expand the $F_Q^{Tr}(z)$ term into its radial and axial components as follows:

$$CFQ * K(z) \geq Max\ over\ i\ [F_{XY}^{Tr}(z) * P^{Tr}(z) * P_{rel}]_i \qquad P_{rel} \geq 0.5 \tag{4-2}$$

Here, $F_{XY}^{Tr}(z)$ is the transient planar radial peaking factor as a function of height and $P^{Tr}(z)$ is the transient core average axial power shape for a given power shape i. $F_{XY}^{Tr}(z)$ may differ from the steady-state, ARO, HFP $F_{XY}(z)$ value due to the following effects: (1) the presence of control rods in axial plane z for the given transient power shape, (2) increases in $F_{XY}(z)$ if $P_{rel} < 1.0$, i.e., if the core is at part-power, and (3) increases in $F_{XY}(z)$ caused by radial transient xenon effects. The last item, the effect on F_{XY} due to transient radial xenon, is discussed in Reference 5.

All three of these effects are directly accounted for in the RAOC analysis. If we define $F_{rad}^{Tr}(z)$ as the "transient" factor that quantifies the increase in the steady-state, HFP, ARO $F_{XY}(z)$ due to these combined effects, we can write the following:

$$F_{XY}^{Tr}(z) = F_{rad}^{Tr}(z) * F_{XY}^{HFP}(z) \tag{4-3}$$

where:

$F_{XY}^{HFP}(z)$ is the predicted, steady-state, HFP, ARO planar radial peaking factor as a function of core height.

Substituting (4-3) into (4-2):

$$CFQ * K(z) \geq Max\ over\ i \left[F \quad (z) * F_{XY}^{HFP}(z) * P^{Tr}(z) * P_{rel}\right]_i \tag{4-4}$$

In (4-4), the limitation of $P_{rel} \geq 0.5$ is dropped for simplicity. It should be understood that the RAOC methodology generates power shapes for relative powers greater than or equal to 0.5.

All of the terms on the RHS of expression (4-4) are analytical values. [

]^{a,c}

[ ]^{a,c} (4-5)

In (4-5) we have also included the factor U_F that accounts for measurement and manufacturing uncertainties. Rearranging this slightly:

[ ]^{a,c} (4-6)

For most surveillances, the surveillance core condition is HFP (or very near HFP) with control rods almost fully withdrawn, i.e., near ARO. Also, the limiting RAOC power shape, i.e., the power shape with the minimum margin to the limit, is typically a shape generated at full power conditions. Therefore, for this case:

$$F_{XY}^{HFP}(z) \approx [F_{XY}(z)]_{Surv}^{P} \tag{4-7}$$

$$P_{rel} = 1.0 \quad (4\text{-}8)$$

In these typical circumstances, then, expression (4-6) can be simplified as follows:

[ ]a,c (4-9)

This simplified form of expression (4-6) is instructive because it highlights the primary attributes of this formulation. [

]a,c

Expression (4-9) assumes that the surveillance condition is HFP, ARO. We can generalize the formulation for all surveillance conditions as follows: The LHS of expression (4-6) is the $F_Q(z)$ limit at HFP. As discussed in Section 2, the $F_Q(z)$ limit is an inverse function of the surveillance power level. To implement this functionality in (4-6), both sides of the expression must be divided by the surveillance relative power P_{rel}^{ss} or 0.5 if the surveillance relative power is ≤ 0.5. This is indicated by the following:

[ ]a,c $for\ P_{rel}^{ss} > 0.5$ (4-10)

[ ]a,c $for\ P_{rel}^{ss} \leq 0.5$ (4-11)

In the remainder of this derivation, we will work with expression (4-10) and, at the end, generalize the result for surveillance relative powers below 0.5.

The first bracketed expression on the RHS of (4-10) is the new analytical factor T(z) that replaces W(z) for RAOC plants. Therefore:

[ ]a,c (4-12)

We can write this more simply as:

[ ]a,c (4-13)

[

]a,c

Like the W(z) factors in the current formulation, the T(z) factors in the new formulation will be pre-calculated and included in the COLR. Therefore, it is necessary to assume some reference surveillance condition for their calculation. Specifically, a reference surveillance condition must be assumed for the denominator of expression (4-13). Generally, the steady-state reference surveillance condition assumed will be HFP, ARO, but other reference conditions could be assumed, e.g., for surveillance specific T(z) factors at a reduced power level. The following expression indicates that the COLR T(z) factors are based on some reference surveillance condition assumed in the denominator of the expression:

[ ]a,c (4-14)

where:

> P_{rel}^{Ref} is the reference relative power level and $[F_{XY}(z)]_{Ref}^{P}$ is the reference predicted radial peaking factor at elevation z assumed in generating the COLR T(z) functions.

However, since the actual surveillance may not coincide with the surveillance conditions assumed in generating T(z), the COLR T(z) values can be modified <u>at the time of the surveillance</u> to provide T(z) values more appropriate to the actual surveillance conditions. The following expression indicates the required modifications:

[ ]a,c (4-15)

The ratio $\left(P_{rel}^{Ref}/P_{rel}^{ss}\right)$ represents a straightforward modification to the T(z) factors. At the time of the surveillance, the surveillance power level P_{rel}^{ss} is known. Also, P_{rel}^{Ref} is a known assumption and will usually equal 1.0. Consequently, this modification factor will usually be $(1/P_{rel}^{ss})$. This same modification is currently made to the W(z) factors supplied in the COLR. It is only necessary because of the scaling of the F_Q limit with power level.

[

]^a,c This is shown as follows.

Using (4-12) and (4-15), expression (4-10) can be rewritten as the following:

[ ]^a,c (4-16)

[

]^a,c

If we define this ratio as $A_{XY}(z)$, i.e., an adjustment factor for the radial peaking factor, expression (4-16) becomes:

$$\frac{CFQ*K(z)}{P_{rel}^{ss}} \geq [T(z)]^{COLR} * \left(\frac{P_{rel}^{Ref}}{P_{rel}^{ss}}\right) * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \quad (4\text{-}17)$$

where:

[ ]^a,c (4-18)

These expressions indicate that F_{XY} is a function of z. F_{XY}, however, is actually a function of a number of variables including height (z), relative power, control rod position, and cycle burnup. For a given surveillance, the cycle burnup is fixed. To separate the correction factor A_{XY} into its component correction factors related to power level and control rod position, the following definitions will be made with respect to the analytical F_{XY} values for a surveillance at a given cycle burnup:

$F_{XY}(z, P_{Surv}, R_{Surv}) \equiv [F_{XY}(z)]_{Surv}^{P} \equiv$ predicted radial peaking factor at elevation z, surveillance power level P_{Surv}, and surveillance control rod position R_{surv}

$F_{XY}(z, P_{Ref}, R_{Ref}) \equiv [F_{XY}(z)]_{Ref}^{P} \equiv$ predicted radial peaking factor at elevation z, reference power level P_{REF}, and reference control rod position R_{Ref}

$F_{XY}(z, P_{Surv}, R_{Ref}) \equiv$ predicted radial peaking factor at elevation z, surveillance power level P_{Surv}, and reference control rod position R_{Ref}

Expression (4-18) can then be rewritten as follows:

$$[\qquad]^{a,c} \qquad (4\text{-}19)$$

If we now make the following definitions:

$$[\qquad]^{a,c} \qquad (4\text{-}20)$$

$$[\qquad]^{a,c} \qquad (4\text{-}21)$$

we can rewrite (4-19) as follows:

$$[\qquad]^{a,c} \qquad (4\text{-}22)$$

Therefore, expression (4-17) becomes,

$$\frac{CFQ*K(z)}{P_{rel}^{SS}} \geq [T(z)]^{COLR} * \left(\frac{P_{rel}^{Ref}}{P_{rel}^{SS}}\right) * F_{RC}(z) * F_{PC}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad (4\text{-}23)$$

In this expression, F_{RC} and F_{PC} respectively correct the surveillance for the presence of the control rod and for differences in the reference and surveillance power levels, removing the inconsistency between the reference conditions assumed in generating the T(z) factors and the actual surveillance core condition.

For convenience, when the $[T(z)]^{COLR}$ values are calculated for inclusion in the COLR, the P_{rel}^{Ref} term in the denominator of expression (4-14) will be assumed to be equal to 1.0, that is:

$$[\qquad]^{a,c} \qquad (4\text{-}24)$$

(This assumption is also made in the calculation of W(z) values for the COLR in the current formulation.) With this change, the value of P_{rel}^{Ref} in (4-23) is also set to 1.0, so that (4-23) becomes:

$$\frac{CFQ*K(z)}{P_{rel}^{SS}} \geq \frac{[T(z)]^{COLR}}{P_{rel}^{SS}} * F_{RC}(z) * F_{PC}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad (4\text{-}25)$$

Recall that P_{rel}^{ss} is the surveillance relative power level in the F_Q limit expression. When the surveillance relative power level is ≤ 0.5, P_{rel}^{ss} must be set to 0.5 in (4-25). This leads to the following two expressions covering all surveillance power levels:

$$\frac{CFQ*K(z)}{P_{rel}^{ss}} \geq \frac{[T(z)]^{COLR}}{P_{rel}^{ss}} * F_{RC}(z) * F_{PC}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad for\ P_{rel}^{ss} > 0.5 \qquad (4\text{-}26)$$

$$\frac{CFQ*K(z)}{0.5} \geq \frac{[T(z)]^{COLR}}{0.5} * F_{RC}(z) * F_{PC}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad for\ P_{rel}^{ss} \leq 0.5 \qquad (4\text{-}27)$$

Since $F_{RC}(z) * F_{PC}(z) = A_{XY}(z)$, these expressions can be more succinctly written as follows:

$$\frac{CFQ*K(z)}{P_{rel}^{ss}} \geq \frac{[T(z)]^{COLR}}{P_{rel}^{ss}} * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad for\ P_{rel}^{ss} > 0.5 \qquad (4\text{-}28)$$

$$\frac{CFQ*K(z)}{0.5} \geq \frac{[T(z)]^{COLR}}{0.5} * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F \qquad for\ P_{rel}^{ss} \leq 0.5 \qquad (4\text{-}29)$$

Expressions (4-28) and (4-29) are the fundamental expressions for the improved F_Q Surveillance formulation for RAOC plants. To support surveillances, values for $[T(z)]^{COLR}$ will be supplied in the COLR. The Westinghouse core monitoring software will automatically divide these values by P_{rel}^{ss} or 0.5, as appropriate, consistent with expressions (4-28) and (4-29). The same process is used for the W(z) values in the current formulation.

4.2 CALCULATION OF T(Z) FACTORS

[

]^{a,c} W(z) values are calculated at these burnup steps and are included in the COLR. When surveillances are performed at cycle burnups intermediate to the explicitly analyzed burnups, standard interpolation methods are employed by the core monitoring software to generate W(z) values appropriate for that particular cycle burnup. The same process will be employed for the T(z) factors in the improved F_Q Surveillance formulation.

The relevant expression for calculating the COLR T(z) factors for a particular burnup is expression (4-24), which is:

[ ]^{a,c} (4-30)

Normally, the reference condition assumed for calculation of the radial peaking factor in the denominator is HFP, ARO, EQXE. However, a different reference condition could be assumed. For example, if T(z) values were desired for a specific reduced power operating state, surveillance specific T(z) values could be generated using (4-30) by including radial peaking factors consistent with that state in the denominator of the ratio. The numerator of the ratio, which is independent of the surveillance condition, is determined by examining all of the power shapes generated in the RAOC analysis for the particular burnup being analyzed. These "surveillance-specific" T(z) values could be included in the COLR.

The relationship between T(z) and W(z) is very simple and is easily established by comparing the expression for the COLR T(z) with the expression for the COLR W(z). The relevant expression for the COLR W(z) is expression (3-14), which is:

$$[\qquad\qquad]^{a,c} \tag{4-31}$$

Using expression (2-10):

$$[\qquad\qquad]^{a,c} \tag{4-32}$$

Comparing (4-30) and (4-32), it is apparent that:

$$[\qquad\qquad]^{a,c} \tag{4-33}$$

[

]a,c

There is a subtle difference in the current F_Q Surveillance formulation and the improved formulation that requires some discussion. In the current formulation, W(z) is multiplied by the measured $F_Q(z)$ at the surveillance condition to determine the "measured" transient $F_Q(z)$ for the surveillance (see expression (3-13)). By virtue of using the measured $F_Q(z)$, the axial power distribution effects of the fuel assembly spacer grids are directly captured. The fuel assembly spacer grids, which are modest neutron absorbers, depress the local power near the grids. As a result, there is a slight increase in power—effectively, an increase in P(z)—in the spans between the grids. Because the new formulation uses the measured $F_{XY}(z)$ instead of the measured $F_Q(z)$, the effects of the grids are not directly captured via measurement. To address this, the new formulation will capture the peaking factor effects of the grids in one of two ways: (1) the grids will be explicitly modeled in the core models used to determine $F_Q^{Tr}(z)$ in the numerator of the $[T(z)]^{COLR}$ expression, or (2) the grids will be implicitly modeled by smearing their material within the model and increasing $F_Q^{Tr}(z)$ by a small factor to account for the additional axial power peaking in the spans between grids.

The second method is the standard method currently used in the RAOC (and CAOC) power shape analyses—not to generate W(z) values, but as part of the reload safety evaluation analyses performed to confirm that the $F_Q(z)$ limit will be met. Current core models typically do not explicitly model the grids. So, when these models are used to calculate $F_Q(z)$, a grid factor is always included in the final $F_Q(z)$ estimate. In the future, however, core models that explicitly model the spacer grids may be used, in which case the use of an ancillary grid factor will be unnecessary.

4.3 CALCULATION OF $A_{XY}(Z)$ AND ITS SUB-FACTORS

For the vast majority of surveillances in the vast majority of plants, the $A_{XY}(z)$ adjustment factors will be unimportant. The reasons for this are:

1. Virtually all plants are operated in baseload mode at nominal operating conditions with control rods nearly fully withdrawn. Consequently, if the reference conditions assumed for generating the T(z) values are HFP, ARO, EQXE, these conditions will usually agree closely with the actual surveillance core conditions. So, $F_{PC}(z)$ and $F_{RC}(z)$ will very nearly equal 1.0; therefore, $A_{XY}(z)$ will nearly equal 1.0.

2. For surveillances, many plants use a core model from an on-line core monitoring system that has been calibrated to the measured core via periodic flux maps and continuous readings from incore and excore instrumentation (e.g., excore detectors, thermocouples, or fixed incore detectors). The power distribution in the calibrated core model is effectively the measured power distribution. During a surveillance, this calibrated core model is taken to HFP, ARO, EQXE conditions. The resulting $F_Q(z)$ from that model is the measured $F_Q(z)$ used in the F_Q Surveillance formulation. For these plants, then, every surveillance is at the correct reference conditions; therefore, $A_{XY}(z)$ will always equal 1.0.

3. As Tables 3-1 and 3-2 show, the power distribution sensitivity of the radial peaking factor is not large. For, power levels $\geq$ 70% RTP, the ratio of the full power F_{XY} to the part power F_{XY} (which is F_{PC}) was > 0.98, which corresponds to a less than 2% correction.

4. Tables 3-3 and 3-4 show that F_{RC}, the peaking factor correction for control rods, can be significant. However, at high power levels, the lead control bank is rarely inserted deeply. Furthermore, the axial location of the minimum margin is rarely in the small region at the top of the core where the lead control bank could be present.

5. The current F_Q Surveillance formulation does not include the $F_{PC}(z)$ and $F_{RC}(z)$ corrections, even though it legitimately could (see Section 7). Despite this, F_Q margin issues occur very infrequently, which implies that ignoring these effects does not pose significant difficulties in meeting limits for the vast majority of surveillances.

6. Technical Specifications require re-verification of transient $F_Q(z)$ whenever power is increased by more than 10% relative to the last verification of $F_Q(z)$. Consequently, surveillances will always occur at high powers near the core conditions assumed in generating the COLR T(z) factors and where transient F_Q margin is near its minimum value.

Given these six reasons, a good argument could be made that explicit inclusion of the $A_{XY}(z)$ factors in surveillances is unnecessary. However, use of these factors should be an option in the rare circumstance where a plant needs margin to avoid an operating space or power level reduction. With this in mind, two methods are discussed in the following subsections for incorporating these adjustment factors into surveillances. They are discussed in order of increasing complexity.

4.3.1 Method 1: $A_{XY}(z)$ is Unity

The current F_Q Surveillance formulation makes no adjustment in the radial peaking factors when the surveillance conditions differ from the reference conditions. This has not led to frequent or significant margin issues. Consequently, assuming that $F_{PC}(z) * F_{RC}(z) = A_{XY}(z) = 1.0$ is a reasonable option that will in all likelihood result in conservative surveillances for off-nominal conditions. This option, however, is not so conservative that margin issues are likely to ensue. In other words, with this method, the limiting transient F_Q margin will in all likelihood be underestimated if the surveillance conditions are at a lower power than the reference conditions and/or the lead control bank is inserted, but this underestimation will likely be small in most circumstances.

In theory, it is possible to slightly over-estimate the minimum margin by assuming that $A_{XY}(z) = 1.0$. This would only occur, however, if the predicted radial peaking factor at the surveillance condition is less than the predicted radial peaking factor at the reference condition, i.e., if:

[ ]^{a,c} (4-34)

at the minimum margin location. Since peaking factors tend to increase with rod insertion and reduced power level, this inequality is unlikely to be true at the axial plane of minimum margin.

Consequently, setting $A_{XY}(z) = 1.0$ is a viable option and the simplest one. This will be the default option presented in the COLR; that is, if explicit values for $A_{XY}(z)$ or its sub-factors are not determined via the other methods discussed in the following subsections, then these factors shall be assumed to be 1.0.

4.3.2 Method 2: Direct Calculation of $A_{XY}(z)$ for the Surveillance Condition

The most convenient and direct method of determining explicit values for $A_{XY}(z)$ or its sub-factors is to calculate them at the time of the surveillance using a model of the core generated using approved methods. The method for doing this is essentially expression (4-22), which is:

[ ]^{a,c} (4-35)

In this method, $A_{XY}(z)$ is determined directly through two core calculations: one at the reference conditions assumed for the COLR T(z) factors, e.g., HFP, ARO, EQXE, and a second at the actual surveillance conditions, which may have a reduced power level and some lead control bank insertion. Since surveillances are typically performed at or near equilibrium conditions, equilibrium xenon may be assumed in this second calculation for simplicity.

An example of this method was presented in Table 3-4. Table 3-4 provides the ratio of the radial peaking factors at the reference condition of ARO, HFP, EQXE and at a surveillance condition corresponding to 26.4% RTP and with the lead bank positioned at 176 steps withdrawn. For this case, the $A_{XY}(z)$ factors would result in corrections of the transient $F_Q(z)$ on the order of a few percent. Note that for this case, all of the $A_{XY}(z)$ factors are less than 1.0. Thus, applying these factors would slightly decrease the maximum transient $F_Q(z)$ and increase the "measured" transient F_Q margin. As discussed earlier, one can think of

these factors as correcting the COLR T(z) to the surveillance condition or, equivalently, correcting the measured $F_{XY}(z)$ to the reference condition.

This method will be included in the COLR as an appropriate method to account for differences between the reference and surveillance conditions in the surveillance transient F_Q margin assessment. If this method is used, the values will be determined on a surveillance specific basis. Note that the values of $A_{XY}(z)$ will not be included in the COLR; rather, only the method will be referenced.

4.4 MEASUREMENT OF $F_{XY}(Z)$

In this new formulation, the key factor being measured is the $F_{XY}(z)$. The measured $F_{XY}(z)$ is used to normalize the transient $F_Q(z)$ analysis to the radial peaking factors of the measured core. Of course, $F_{XY}(z)$ is being measured in the current formulation, too, but as a component of the measured $F_Q(z)$. The measured $F_{XY}(z)$ can be directly obtained from the measured $F_Q(z)$ through use of expression (2-10), i.e.:

$$F_{XY}^M(z) = \frac{F_Q^M(z)}{P^M(z)} \tag{4-39}$$

There are a number of plants (primarily CAOC plants) that confirm $F_Q(z)$ indirectly by measuring $F_{XY}^M(z)$ and then comparing this measurement to an $F_{XY}(z)$ limit. These plants utilize the surveillance approach discussed in Technical Specification 3.2.1A in Reference 1, which, as mentioned earlier, is the Heat Flux Hot Channel Factor Technical Specification for CAOC $F_{XY}(z)$ plants. The bases for this TS specify that core plane regions within ±2% of the grid plane regions are excluded from the surveillance. The 2% value corresponds to 2% of the core height or about 2.9 inches for a 12 foot core. The reason for this exclusion is a concern with respect to measuring F_{XY} in this region. If the flux traces from the moveable detector system are not all well-aligned with respect to their grid depressions, it is possible to get "anomalous" F_{XY} measurements. This could occur, for example, if a flux trace were misaligned such that a non-grid axial point was mispositioned into a grid plane. This would cause the measured F_{XY} for that grid plane to be unrealistically large, resulting in an anomalous margin reduction relative to the F_{XY} limit.

For the current formulation, where $F_Q(z)$ is measured, this issue is not much of a problem since the axial powers at the grid elevations are depressed. Even if the measured F_{XY} is anomalously large at a grid plane because of a trace misalignment or other measurement difficulty, the effect is offset by the grid depression. There are no grid exclusions in the current F_Q Surveillance TS.

In the new formulation, grid region exclusions are probably not necessary for two reasons:

1. Future core models may model the grids. Consequently, the grid depressions will be present in the analytical power shapes, much as they are currently in the measured power shapes.

2. Even if the grids are not included in the model, trace alignment is generally good and the measured F_{XY} values will be accurate.

With respect to this second point, Figures 4-1 through 4-7 show measured $F_{XY}(z)$, $F_Q(z)$, and P(z) values from flux maps for six different plants. Figures 4-1 through 4-4 are for BOL, while Figures 4-5 through 4-7 are for EOL. Note that for Figures 4-1 through 4-6 there are no significant irregularities in these

curves that would indicate serious trace alignment issues, i.e., there is no indication of an F_{XY} point that is significantly offset from its neighboring points that would indicate a local trace alignment anomaly. In general, the $F_{XY}(z)$ values are well-behaved in the central core region outside of the standard exclusion zone (top and bottom 15% of the core).

Figure 4-7, however, does exhibit evidence of trace alignment issues. The large spikes in F_{XY} at locations near the P(z) grid depressions imply that one or more traces were sufficiently misaligned such that detector readings outside or nearly outside the grid region were misaligned into the radial planes of the grids. The anomalous increases in $F_{XY}(z)$ at these locations are large, on the order of 6%.

If trace alignment issues were to occur, they would generally be apparent and correctable using the core monitoring software. However, while F_{XY} measurement issues are likely to be infrequent and inconsequential, especially if future core models model the grid depressions, it is judged to be appropriate to exclude the grid regions from surveillance to avoid even the rare instance of an anomalous measurement that could lead to an anomalous F_Q violation. Because the axial power shape is depressed at the grid locations, these axial planes will not lead the core, i.e., there will always be a core radial plane above or below a grid plane that has a higher $F_Q(z)$. Consequently, the standard F_{XY} measurement exclusions employed in Technical Specification 3.2.1A in Reference 1 will be retained in the Bases of the improved F_Q TS. These exclusions are the following:

a. Lower core region, from 0% to 15% inclusive
b. Upper core region, from 85% to 100% inclusive
c. Grid plane regions, ± 2% inclusive
d. Core plane regions, within ± 2% of the bank demand position of the control banks

These percent values refer to the percent of core height. Note that the top and bottom 15% exclusion zones are typical. The exclusion zone is set on a cycle specific basis to ensure that the limiting margin location is surveilled. Thus, for a specific operating cycle, exclusion zones smaller than 15% may be specified.

4.5 CRUD INDUCED POWER SHIFT CONSIDERATIONS

A central attribute of the F_Q Surveillance methodology is the characterization of non-equilibrium core behavior using analytical factors. For the current F_Q Surveillance formulation, this factor is W(z). For the improved RAOC F_Q Surveillance formulation, this factor is T(z). Both of these factors characterize the transient core peaking factor behavior relative to a reference core state. Use of these factors is only necessary because F_Q Surveillance is periodic, occurring about once a month throughout the operating cycle. A few plants have implemented continuous F_Q surveillance. For such plants, these analytical factors are not needed (when continuous monitoring is operable) since $F_Q(z)$ is monitored continuously during both equilibrium and non-equilibrium operation.

The calculation of T(z) or W(z) involves performing power shape analyses using an analytical model of the core. Thus, there is a necessary assumption in this methodology that the analytical model is a reasonable representation of the core. Low power physics testing and startup power distribution measurements are used to confirm that the core is operating consistent with expectations and has been loaded properly. Consequently, upon completion of this testing, there is high confidence that the core model and the actual core are in good agreement.

Prediction and measurement, however, do not always agree perfectly. As discussed earlier, W(z) factors for RAOC plants are sensitive to differences between the measured and predicted surveillance power shape, typically characterized by the ΔAO value, because the predicted power shape appears in the denominator of the W(z) expression. This term has been eliminated in the T(z) formulation. As a consequence, the improved formulation is insensitive to the kind of normal AO differences that are typically observed. Measured and predicted surveillance power shapes may show differences for many reasons, particularly in the early stages of a cycle. The previous cycle core model is typically depleted assuming a constant power level of 100% RTP, a constant nominal inlet temperature, and with all control rods fully withdrawn. Actual plant operation frequently differs from these idealized conditions. Plant startups are typically modeled as attaining 100% RTP instantaneously with all control rods fully withdrawn, while the actual core undergoes an ascent to power over a period of a few days, typically with some control rod insertion at reduced power levels. Similarly, differences between core modeling and actual operation may occur at the end of a cycle during a coastdown, where the core power level, coolant temperature, and control rod position assumed in the core model may differ from actual plant operation. These operational differences may lead to differences in the axial burnup distribution between the core and the model, and such differences can cause either positive or negative ΔAO deviations to occur.

Occasionally, deviations between measured and predicted steady state power shapes have occurred beyond those attributable to differences in the axial burnup distribution due to past operation. One cause that has been identified in the past for early cycle negative ΔAO is called Integral Fuel Burnable Absorber (IFBA)-induced power shift, which is also known as Axial Offset Deviation (AOD). AOD is characterized by a ΔAO more negative than -3% at the beginning of a cycle, which decreases with depletion of the burnable absorber material. The cause of AOD has been determined to be a redistribution of some of the ZrB_2 material on the IFBA rods during the pellet loading process. After the first several months of operation, the measured axial offset recovers and eventually becomes slightly more positive than predicted. By the end of cycle, the measured axial offset is again close to the predicted value since the ZrB_2 of the IFBA coated rods is almost completely depleted. Improvements have been made in the IFBA rod pellet loading process and to the Westinghouse core design process, so that fewer cores experience AOD and the instances of AOD are less severe.

These kinds of differences, while affecting the steady state power shape, do not significantly affect the range of transient power shapes for a RAOC core. In other words, the denominator of the RAOC W(z) expression, which includes the steady state P(z), can be significantly affected, but the numerator, which includes the maximum transient P(z), is not. This was discussed in Section 3.1 (see Figures 3-3 to 3-5).

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The following attributes can indicate that a core is experiencing or could experience CIPS:

1. ΔAO is more negative than 3% typically starting at cycle burnups between 4,000 and 8,000 MWD/MTU, although manifestation of CIPS later in the cycle is also possible. Figure 4-8 shows the AO behavior of a typical CIPS core.

2. Analysis of sub-cooled boiling rates indicates that the cycle is at risk for CIPS.

3. Examination of axial flux traces for high power feed or once-burned fuel assemblies shows evidence of flux depressions below upper grid spans.

4. There is an indication of lithium return to the coolant following a power reduction.

5. The previous cycle experienced CIPS, and the fuel management for the operating cycle is not significantly different from the fuel management used last cycle.

Improvements to the Westinghouse core design process have made it possible to evaluate the potential for CIPS in a reload cycle and to develop core designs and operating strategies that have significantly reduced the incidence and magnitude of CIPS. Furthermore, CIPS develops slowly and has a characteristic ΔAO signature making it relatively easy to detect. In light of this, it is proposed that, should CIPS occur, the effect of CIPS on transient F_Q margin should be addressed in a timely fashion, e.g., within several weeks of the observed onset. This is proposed rather than the application of generic CIPS penalty factors that are a function of ΔAO. This approach is judged to be reasonable based on the following:

1. Cores are screened for CIPS as part of the core design process.

2. CIPS is a slowly developing phenomenon and has a characteristic ΔAO signature so that it is reasonably obvious when it is occurring.

3. It is very unlikely that minimum transient F_Q margin estimates will be affected even if CIPS occurs.

4. Plants generally have some margin to the F_Q limit that could accommodate CIPS effects, if necessary.

5. Plants rarely operate in a manner that would challenge F_Q limits.

6. Plants have continued to improve primary water chemistry operating practices to reduce the source of crud. The Institute of Nuclear Power Operations (INPO) has increased focus on the chemistry area in the last 5 years; therefore, more plants are adopting industry best practices in the chemistry area. Thus, the incidence of CIPS is decreasing.

In conclusion, if CIPS develops, there is potential for the COLR T(z) factors to be affected, especially in the middle region of the core. However, given that CIPS develops slowly and characteristically, it is proposed that its effects on peaking factor be evaluated in a timely fashion following its observed onset. Appropriate modifications to the COLR T(z) factors and changes to the core operating space can then be determined to ensure that future non-equilibrium operation will not challenge limits.

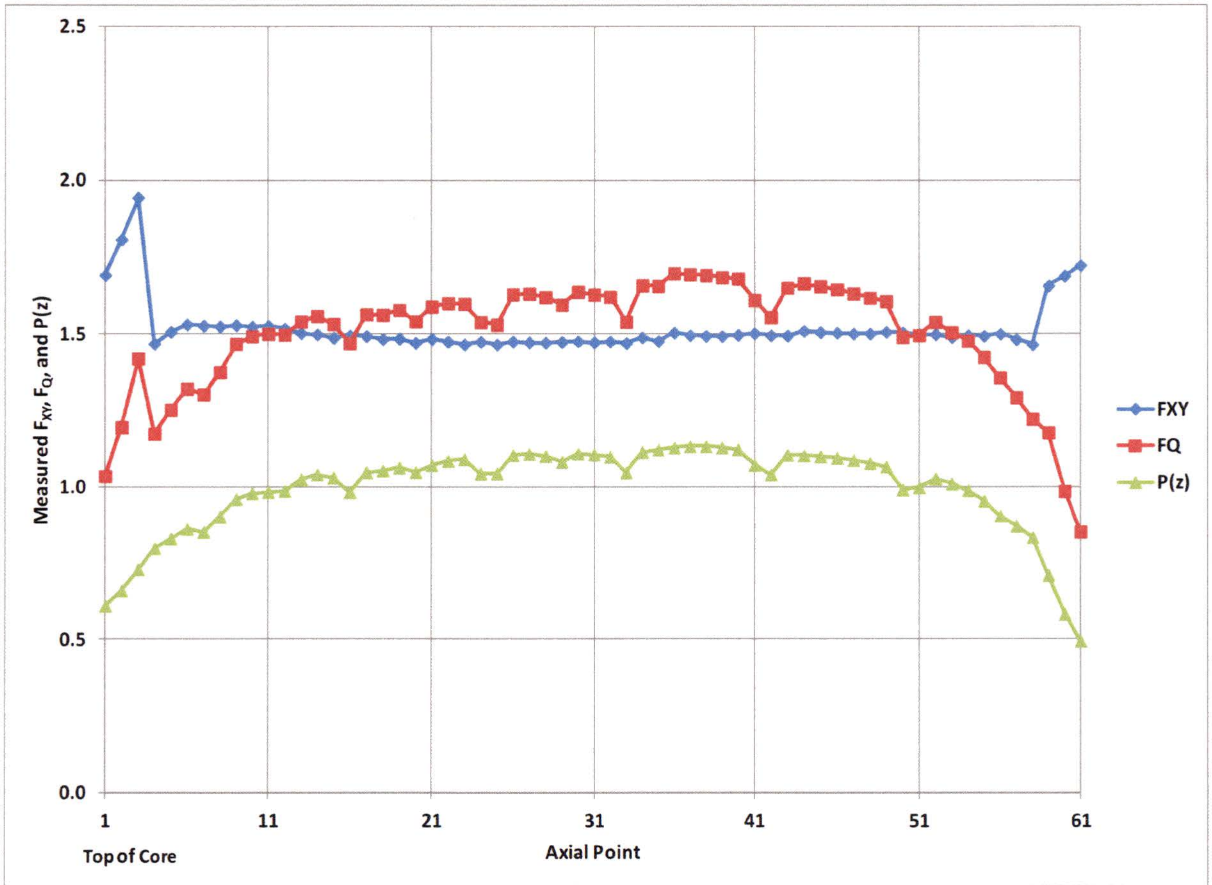

Figure 4-1 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant A at BOL

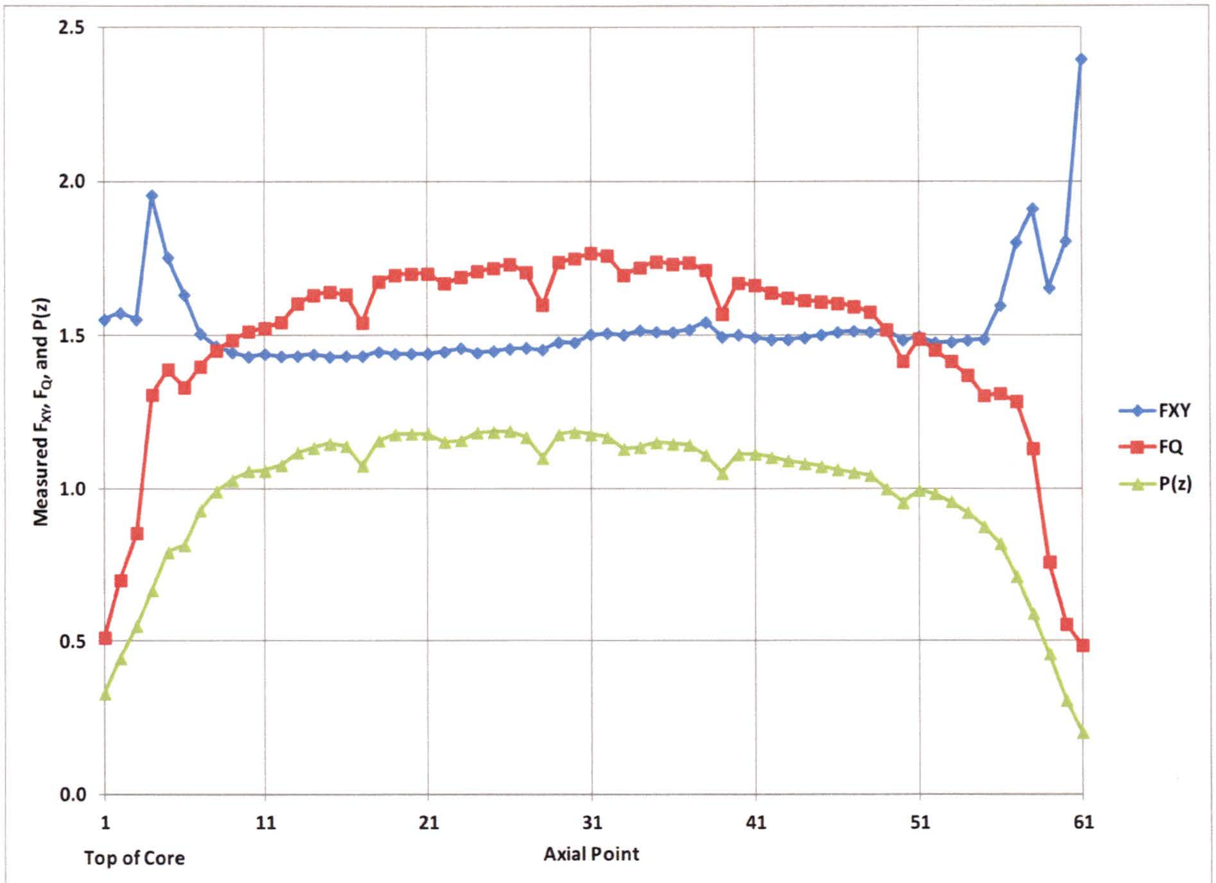

Figure 4-2 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant B at BOL

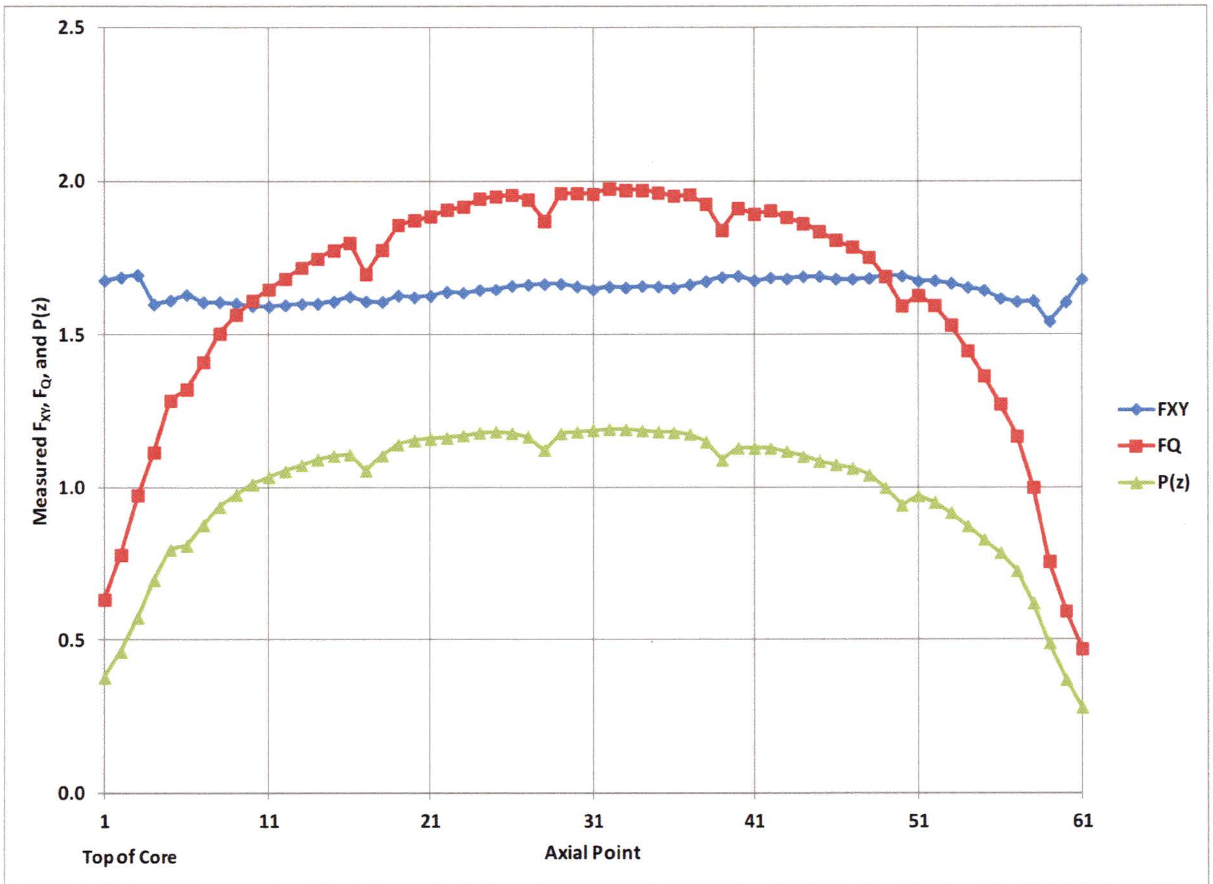

Figure 4-3 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant C at BOL

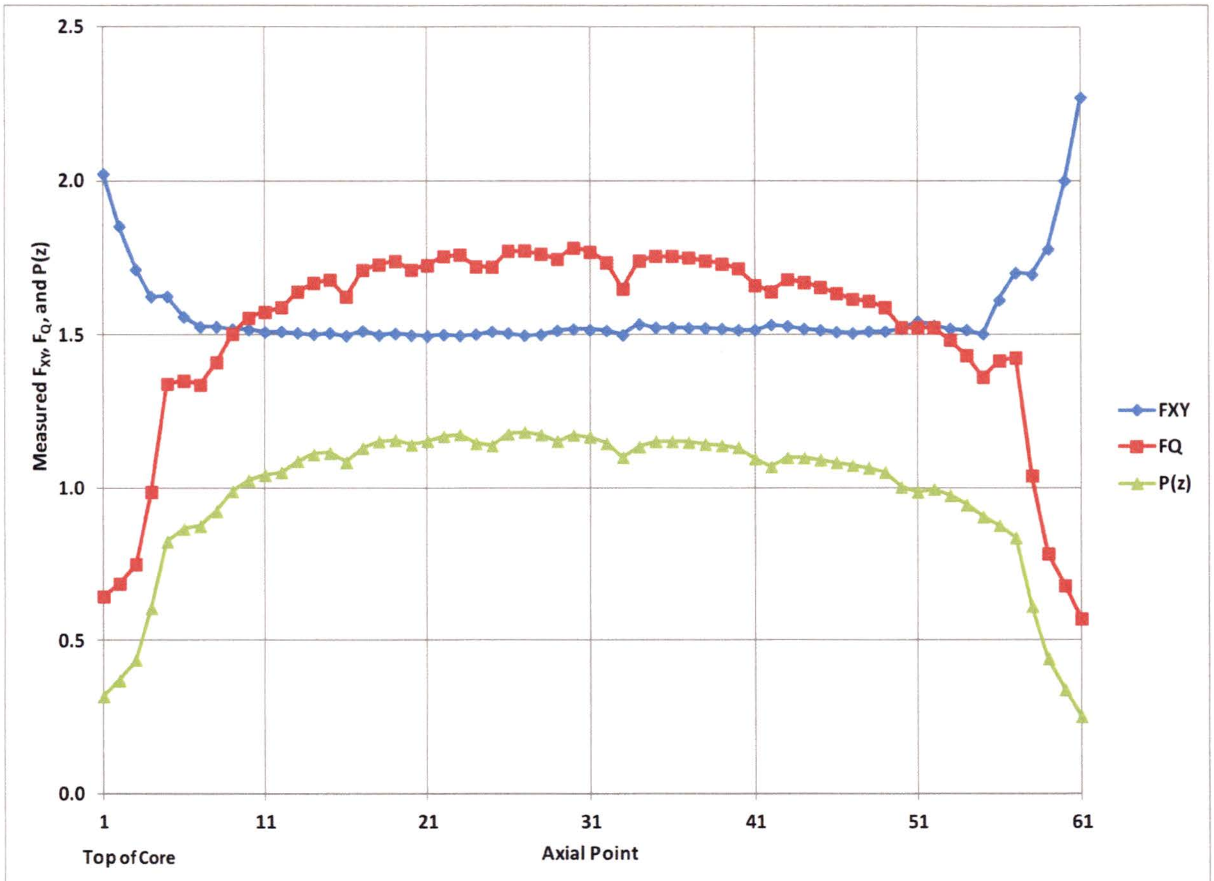

Figure 4-4 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant D at BOL

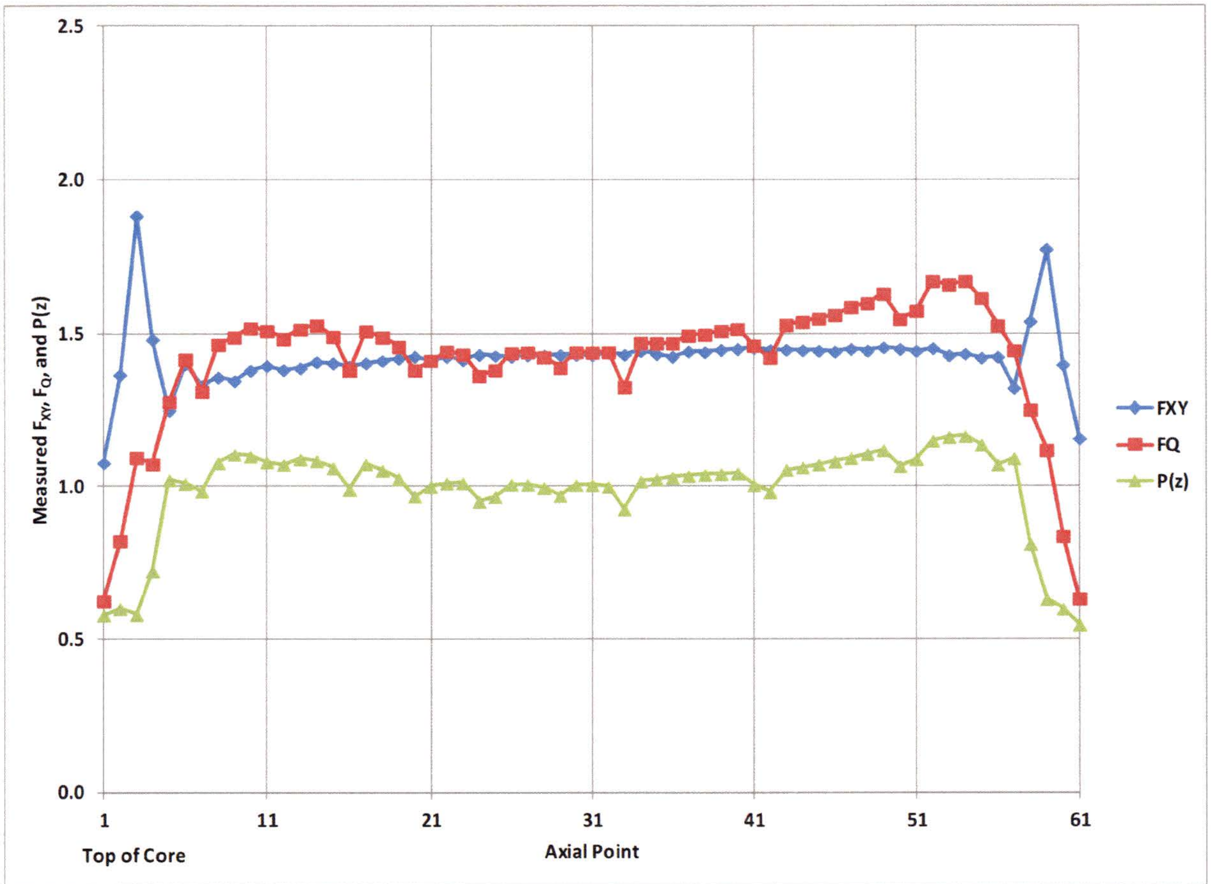

Figure 4-5 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant E near EOL

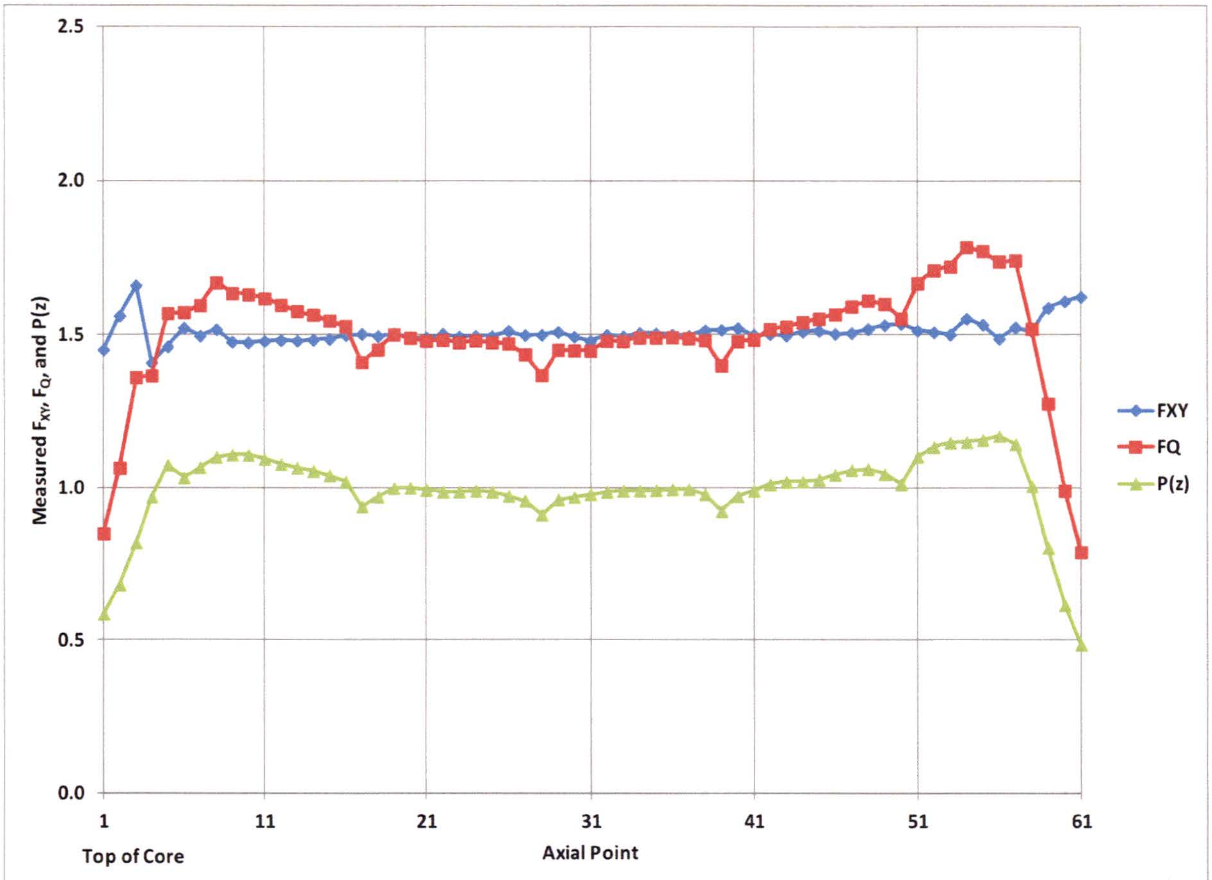

Figure 4-6 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant C near EOL

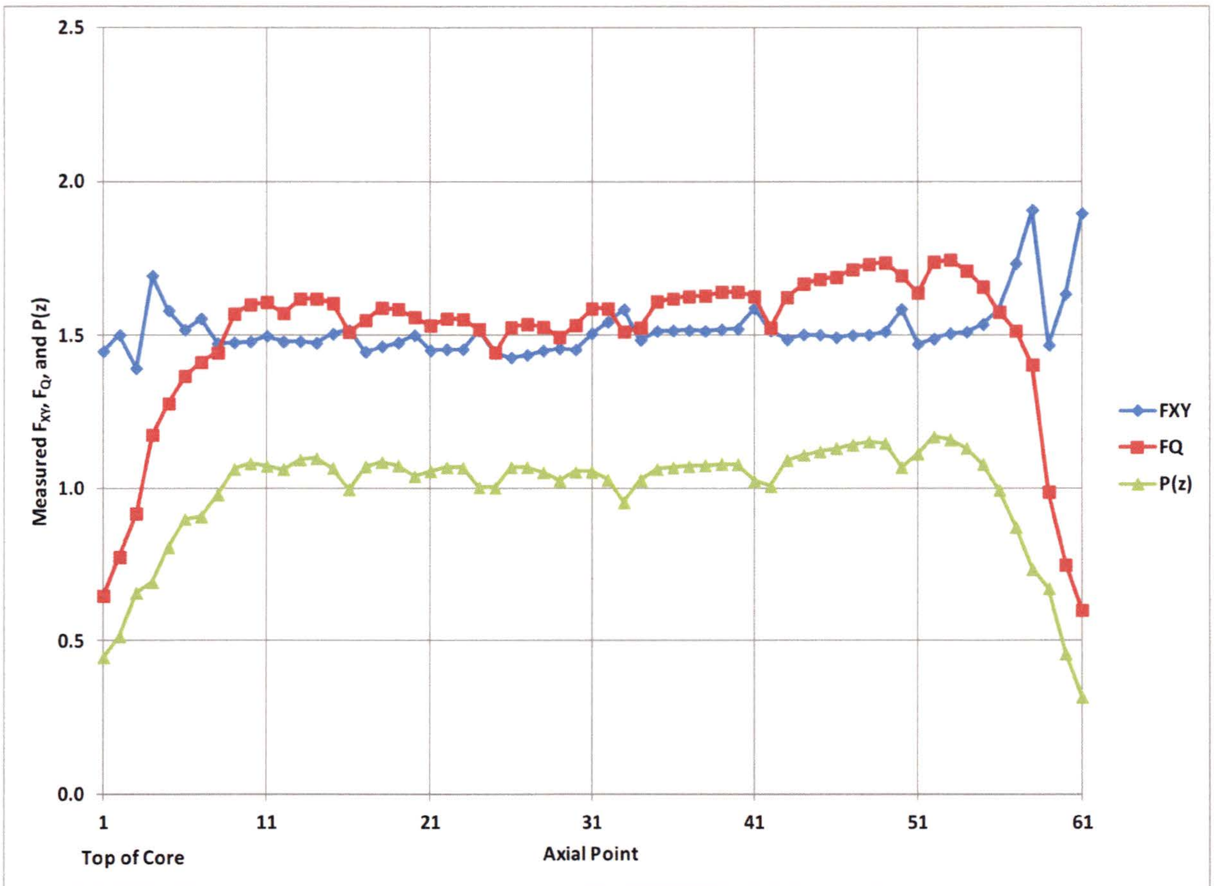

Figure 4-7 Measured $F_{XY}(z)$, $F_Q(z)$, and P(z) for Plant F near EOL

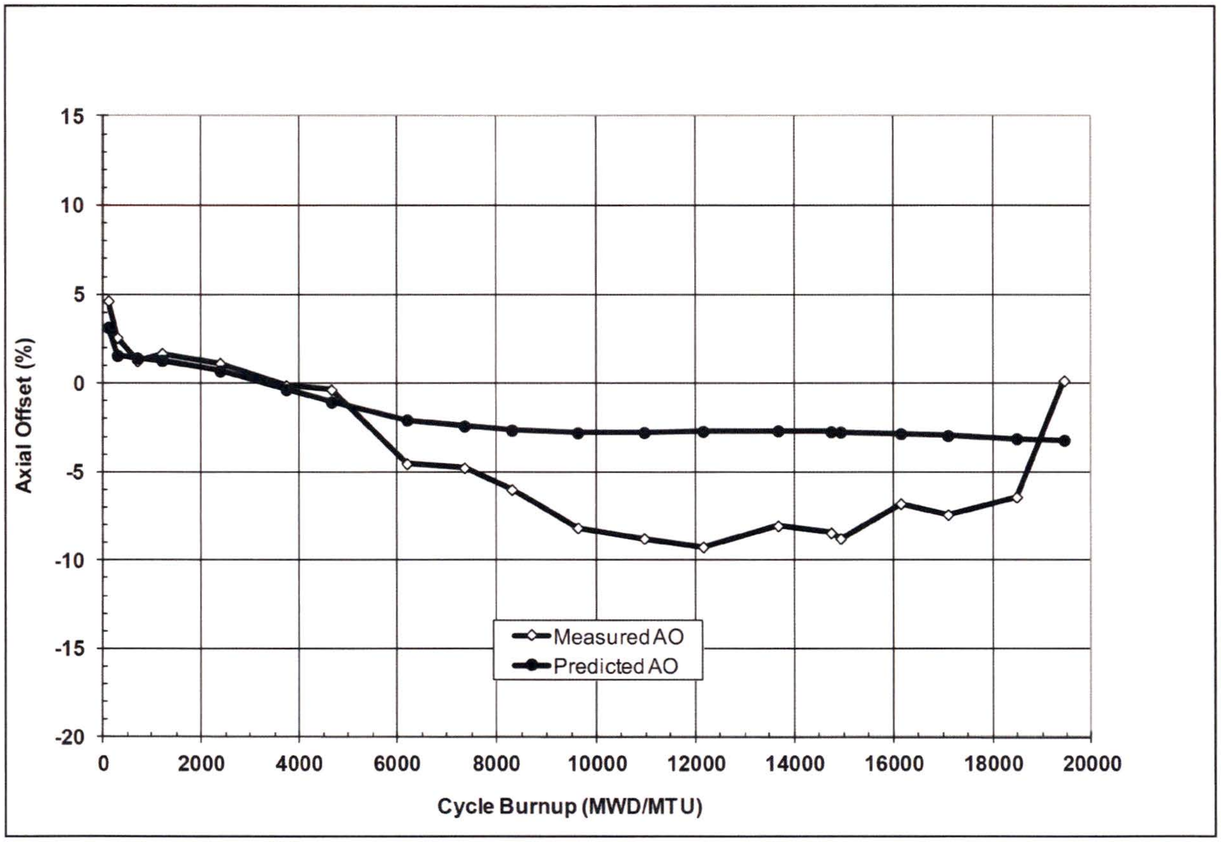

Figure 4-8 Measured and Predicted Axial Offset for a Typical CIPS Core

5 IMPROVED RAOC F_Q SURVEILLANCE TECHNICAL SPECIFICATION

In this section, the improved RAOC F_Q Surveillance Technical Specification will be discussed in detail. This TS would replace Technical Specification 3.2.1B of Reference 1, "Heat Flux Hot Channel Factor $F_Q(z)$ (RAOC — W(z) Methodology)." Methodology additions necessary to support this TS are discussed. The proposed text for the TS and Bases is provided in Appendices A and B, respectively. Note that the Improved CAOC F_Q Surveillance TS is very similar to the improved RAOC F_Q Surveillance TS. The improved CAOC F_Q TS is discussed in Section 8.

5.1 LIMITING CONDITION FOR OPERATION (LCO 3.2.1)

The LCO for the improved version of the RAOC F_Q TS is the same as for the current F_Q TS. It specifies that $F_Q(z)$, as approximated by $F_Q^C(z)$ and $F_Q^W(z)$, shall be within the limits specified in the COLR. As discussed in Section 3.1, $F_Q^C(z)$ is just the equilibrium $F_Q(z)$ at the surveillance condition with appropriate uncertainties included.

For the improved F_Q TS, $F_Q^W(z)$ is defined as follows:

$$F_Q^W(z) \equiv \frac{[T(z)]^{COLR}}{P_{rel}^{ss}} * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * R_j * U_F \qquad for\ P_{rel}^{ss} > 0.5 \tag{5-1}$$

$$F_Q^W(z) \equiv \frac{[T(z)]^{COLR}}{0.5} * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * R_j * U_F \qquad for\ P_{rel}^{ss} \leq 0.5 \tag{5-2}$$

Therefore, $F_Q^W(z)$ is the "measured" transient $F_Q(z)$ scaled by the $1/P_{rel}^{ss}$ or 1/0.5 factor from the F_Q limit expression for $P_{rel}^{ss} > 0.5$ and $P_{rel}^{ss} \leq 0.5$, respectively. In (5-1) and (5-2), the R_j factor has been introduced. This analytical factor, briefly discussed in subsection 3.2.5, accounts for potential increases in the $F_Q^W(z)$ between surveillances. Additional discussion of R_j is provided in Section 5.5.

Using these definitions, we can rewrite the F_Q Surveillance limit expressions (4-26) and (4-27) for the improved formulation as follows:

$$\frac{CFQ*K(z)}{P_{rel}^{ss}} \geq F_Q^W(z) \qquad for\ P_{rel}^{ss} > 0.5 \tag{5-3}$$

$$\frac{CFQ*K(z)}{0.5} \geq F_Q^W(z) \qquad for\ P_{rel}^{ss} \leq 0.5 \tag{5-4}$$

$F_Q^C(z)$ and $F_Q^W(z)$ are compared to the same limit, which is a function of power level and is specified in the COLR. This LCO is unchanged in the improved version of the F_Q Technical Specification. Only the definition of $F_Q^W(z)$ has changed.

5.2 REQUIRED ACTIONS FOR CONDITION A: $F_Q^C(Z)$ NOT WITHIN LIMIT

As discussed in subsection 3.2.2, when $F_Q^C(z)$ exceeds the limit, the core is in an unanalyzed state following the performance of the Surveillance (SR 3.2.1.1) in that the current peak power density in the core is greater than the maximum value assumed in the safety analyses. The Required Actions and Completion Times for the improved version of the RAOC F_Q TS are as follows:

1. Reduce THERMAL POWER ≥ 1% RTP within 15 minutes for each 1% $F_Q^C(z)$ exceeds the limit (Required Action A.1).

2. Reduce the Power Range Neutron Flux – High trip setpoint (Required Action A.2) by ≥ 1% within 72 hours for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.

3. Reduce the Overpower ΔT trip setpoint (Required Action A.3) by ≥ 1% within 72 hours for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.

4. Perform surveillances on $F_Q^C(z)$ and $F_Q^W(z)$ (Required Action A.4) prior to increasing THERMAL POWER above the limit of Required Action A.1.

Required Action A.1 ensures that the core F_Q is consistent with the maximum power density assumptions of the LOCA analysis. By reducing power by 1%, the F_Q * Power value, which is proportional to the power density, will decrease by approximately 1% as well. As noted in subsection 3.2.2, however, the likelihood of $F_Q^C(z)$ exceeding its limit is very remote.

The second and third Required Actions ensure that setpoints are reduced to protect fuel melt and departure from nucleate boiling (DNB) limits for a Condition II event. These conservative actions are justified since the core is operating with a local power density that is significantly higher than expected. The consequences of off-normal power shapes could potentially exceed the consequences evaluated as part of the core safety evaluation.

The final Required Action simply ensures that all limits are met prior to increasing core power above the reduced limit of the first Required Action.

5.3 REQUIRED ACTIONS FOR CONDITION B: $F_Q^W(Z)$ NOT WITHIN LIMIT

The Required Actions for Condition B in the improved RAOC F_Q TS are different relative to the current F_Q TS. If $F_Q^W(z)$ is not within its limit, it will be required to:

1. Within 4 hours, implement a RAOC operating space specified in the COLR that restores $F_Q^W(z)$ to within its limits (Required Action B.1).

OR

2. Within 4 hours, limit THERMAL POWER to less than RATED THERMAL POWER and reduce AFD limits as specified in the COLR (Required Action B.2.1).

Required Action B.1 permits the implementation of a new RAOC operating space to restore margin if $F_Q^W(z)$ is not within its limit. A RAOC operating space is a unique combination of AFD limits and Control Bank Insertion Limits. The COLR will include one or more RAOC operating spaces. The number of RAOC operating spaces to be included in the COLR will be determined by the utility in conjunction with the core designers. Each RAOC operating space will be pre-analyzed using the approved RAOC analysis methods of Reference 5. T(z) values will be generated for each RAOC operating space and included in the COLR in the same way that W(z) values are provided for the current F_Q TS. In the current F_Q TS, there is a presumption that reducing AFD limits will provide the necessary margin improvement. In the improved F_Q TS, however, the margin improvement can be directly confirmed using the T(z) factors. This will be a very straightforward process and will be discussed in Section 5.5, which discusses the Surveillance Requirements for $F_Q^W(z)$.

When $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits thermal power to less than RTP by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(z)$ limit, then Required Action B.2.1 must be entered and thermal power must be reduced to less than the thermal power limit specified in the COLR. Also, AFD limits must be reduced by the amounts specified in the COLR.

The required limits on thermal power and the required reductions in the AFD limits for Required Action B.2.1 will be determined using the standard RAOC methodology of Reference 5. RAOC power distribution analyses will be performed assuming discrete maximum power levels and specific reduced AFD limits. In a sense, this is analogous to defining another RAOC operating space with maximum thermal power as an additional attribute of the operating space. Analysis of this operating space can quantify an expected margin improvement achieved through reduction in the maximum power level and the AFD operating space. Section 6 will present sample results of these analyses. [

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This margin improvement assessment method for power reduction assumes that the core models provide a reasonable basis for determining the axial location of the minimum margin in the actual core. This is a reasonable assumption since the minimum transient F_Q margin axial location is largely determined by the T(z) functions, which characterize the maximum transient P(z) and are entirely analytical. If $F_Q^W(z)$ exceeds its limit, the cause will be measured radial peaking factors that exceed the predicted radial peaking factors assumed in the analysis. The causes of these peaking factor differences could be, for example, unexpected core tilts or underprediction of the hot assembly relative power. In this case, the minimum $F_Q^W(z)$ margin will decrease but its axial location will not be appreciably different. Effectively, $F_Q^W(z)$ will be scaled higher by the larger measured radial peaking factors.

As a practical matter, the number of discrete reduced power level evaluations included in the COLR will be limited to three or less, although an individual utility may opt for additional evaluation levels. In the sample analysis presented in Section 6, evaluations were performed for 95% and 90% RTP. If the required margin improvement exceeds the level of any pre-analyzed thermal power limit, the COLR will specify that thermal power should be limited to < 50% RTP. This is prudent since it means that a very large and unusual core anomaly is present. Such a core anomaly should be evaluated extensively with respect to continued operation at high power levels. It is likely that other TS, such as the Nuclear Enthalpy Rise Hot Channel Factor TS, would also require a power level reduction in the presence of such a large anomaly.

If Required Action B.2.1 is entered, the improved RAOC F_Q TS also requires the following:

1. Within 72 hours, reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER (Required Action B.2.2).

2. Within 72 hours, reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER (Required Action B.2.3).

These actions are consistent with the current F_Q TS whenever a reduction in the maximum allowable power is specified. They are conservative measures that provide protection against the consequences of Condition II transients in light of the larger local peaking factors that resulted in $F_Q^W(z)$ exceeding its limit.

Finally, the last Required Action for Condition B is the following:

3. Prior to increasing THERMAL POWER above the limit of Required Action B.2.1, perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.2.4).

This Required Action is essentially the same as in the current F_Q TS except that the Completion Time has been specifically tied to Required Action B.2.1, which specifies the required limit on thermal power.

The Required Action for Condition C, "Required Action and Completion Time not met," is unchanged in the improved RAOC F_Q TS. The Required Action is to be in MODE 2 within 6 hours.

5.4 SURVEILLANCE REQUIREMENTS FOR $F_Q^C(Z)$

In the improved F_Q TS, the Surveillance Requirements for $F_Q^C(z)$ are very similar to the Surveillance Requirements in the current F_Q Technical Specification. In the improved F_Q TS, SR 3.2.1.1 will require verification that $F_Q^C(z)$ is within its limit. The Frequencies for SR 3.2.1.1 will specify that $F_Q^C(z)$ must be verified to be within its limit as follows:

a. Once after each refueling prior to THERMAL POWER exceeding 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

These Frequencies permit power escalation following a refueling to no more than 75% RTP prior to performance of the first verification of $F_Q^C(z)$. They also require verification following large power level increases and periodically throughout the operating cycle. Together, these three Frequencies are unambiguous and appropriately verify $F_Q^C(z)$ during the initial power escalation and throughout the entire operating cycle until the next refueling outage. As discussed in subsection 3.2.4, the note modifying SR 3.2.1.1 has been eliminated. Also, the second Frequency has been increased from 12 to 24 hours. This Frequency of 24 hours is contained in some plant Technical Specifications and is a reasonable time period in which to perform this verification given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

5.5 SURVEILLANCE REQUIREMENTS FOR $F_Q^W(Z)$

SR 3.2.1.2 requires verification that $F_Q^W(z)$ is within its limit. This is unchanged in the improved F_Q TS. As discussed in subsection 3.2.5, however, the Frequencies for SR 3.2.1.2 are changed relative to the current F_Q TS. The new Frequencies for SR 3.2.1.2 specify that $F_Q^W(z)$ must be verified to be within its limit as follows:

a. Once after each refueling within 24 hours after THERMAL POWER exceeds 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

The Frequencies in a. and b. are changed relative to the current F_Q TS.

In the current F_Q TS Frequency, the initial verification of $F_Q^W(z)$ following a refueling must occur <u>prior</u> to exceeding 75% power. In the improved F_Q TS, the initial verification must occur within 24 hours after THERMAL POWER exceeds 75% RTP. This Frequency is contained in some plant Technical Specifications with 12 hours specified instead of 24 hours.

As discussed briefly in subsection 3.2.5, this change is justified for the following reasons:

1. Core power distribution measurements and physics testing performed at low powers (<50% RTP) confirm that the core is loaded properly and provide assurance that the core is operating consistent with expectations. In conjunction with the fact that the reload analysis confirms in advance that the transient F_Q limit will be met for the current operating space at the beginning of the cycle using an NRC approved methodology, this provides an expectation that the first

performance of SR 3.2.1.2 after a refueling will successfully confirm that the transient F_Q limit is met.

2. Surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. This was discussed in Section 3.1. The improved F_Q Surveillance formulation for RAOC plants mitigates this concern to some extent by largely eliminating sensitivity to ΔAO. Performing this initial verification after exceeding 75% power, however, ensures that the surveillance will be performed with appropriate steady state peaking factors measured at or near the power level and core conditions where future non-equilibrium operation has the potential for challenging fuel limits.

Power levels of $\leq$75% RTP are typically non-limiting for minimum transient $F_Q^W(z)$ margin because of the increase in the F_Q limit with reduced power. The new Frequency will ensure that verification of $F_Q^W(z)$ is performed prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could be challenged. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

The second Frequency was increased from 12 to 24 hours consistent with the change made to SR 3.2.1.1. Again, this Frequency is contained in some plant Technical Specifications.

As discussed in subsection 3.2.5, the note modifying SR 3.2.1.2 has been eliminated. The intent of this note in the current F_Q TS is to account for potential increases in $F_Q^W(z)$ between surveillances, which could be a month apart if the core is operating at RTP. It requires application of the greater of a 1.02 factor or a factor specified in the COLR whenever measurements indicate that the maximum value of $F_Q^C(z)/K(z)$ has increased. Alternatively, SR 3.2.1.2 must be repeated once per 7 EFPD until $F_Q^W(z)$ is within limits with the penalty factor applied or two successive flux maps indicate that $F_Q^C(z)/K(z)$ has not increased.

In the improved F_Q TS, the required penalty factor, R_j, is always applied, regardless of the trend in previous measurements. The R_j penalty factor is now simply part of the definition of $F_Q^W(z)$ (see expressions (5-1) and (5-2)) and is determined in the same manner as for the current F_Q TS (Reference 5). The COLR will provide the required penalty factors as a function of cycle burnup. Required penalty factors will be provided for each ROS. When margin is predicted to increase in the upcoming operating period, the COLR will indicate a penalty factor of 1.0, i.e., no penalty. A penalty factor greater than 1.0 will be required whenever the <u>minimum margin</u> to the $F_Q^W(z)$ limit is predicted to decrease in the upcoming period.

In the current F_Q TS, the application of the penalty factor for the next operating period is predicated upon an increase in the measured value of $F_Q^C(z)/K(z)$ over the <u>previous</u> operating period. While a change in measured $F_Q^C(z)/K(z)$ is a good figure of merit for margin changes, the improved F_Q TS is more appropriate and rigorous since future decreases in margin are the relevant concern and are directly employed in determining whether a penalty is necessary. This avoids any lag in the application of the penalty factor caused by the requirement for two successive measurements, which could be a month or more apart, to indicate a decrease in margin. Therefore, the revised note will better capture the expected trend of the margin based on predictions. By eliminating the note, however, the option to perform more

frequent surveillances in lieu of applying the penalty factor is also eliminated. It will be necessary to demonstrate that the LCO is met with the COLR R_j factor applied. If the LCO is not met, then the Required Actions must be performed to restore margin. The current F_Q TS, requires a minimum penalty of 2% regardless of the magnitude of the increase in measured $F_Q^C(z)/K(z)$. In the improved F_Q TS, there is no minimum penalty factor for periods of decreasing margin. The penalty factor will be consistent with the predicted margin trends. This eliminates the problem of trivial changes in margin requiring a 2% penalty.

The magnitude of the penalty factor included in the COLR is an analytical quantity independent of measurement. Consequently, the current methods used to determine this penalty remain appropriate. Reference 5 does not provide many methodology details with respect to calculation of these penalty factors. The current method used to calculate them is briefly described in the following.

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]a,c

From (4-31), we have:

$$\left[\qquad \right]^{a,c} \qquad (5\text{-}6)$$

Then:

[ ]^{a,c} (5-7)

From (5-5), the minimum margin to the F_Q limit at BU_j will occur at the axial location where the ratio $F_Q^W(z,BU_j)/K(z)$ is maximized. Therefore:

[ ]^{a,c} (5-8)

[ ]^{a,c} This is accomplished with the following ratio:

[ ]^{a,c} (5-9)

The factor R_j can be used to account for the expected decrease in margin due to non-equilibrium operation over the next EFPM. When applied to the measured $F_Q^W(z,BU_j)$, the margin is decreased by the maximum amount predicted over the next EFPM. If R_j is less than 1.0, the margin is expected to increase, and a value of 1.0 would be indicated in the COLR for that burnup.

Note that the above discussion employs W(z) values calculated for the COLR reference condition (HFP, ARO, EQXE) . In this context, W(z) is simply used as a means of obtaining the predicted maximum transient $F_Q(z)$*Power at the particular burnup of interest. T(z) can been used to accomplish the same purpose. From expression (4-33), we have the following:

[ ]^{a,c} (5-10)

Substituting into (5-7):

[ ]^{a,c} (5-11)

Consequently, W(z) factors or T(z) factors may be used to determine the analytical maximum transient F_Q*Power at the burnup of interest. Therefore, both factors may be used to determine R_j.

Values for R_j will be included in the COLR for each RAOC operating space. In generating the factors, it will be assumed that an EFPM is equal to at least 31 EFPD, corresponding to the maximum surveillance

interval in SR 3.2.1.2. Values larger than 31 EFPD may be used for conservatism or to account for permitted extensions of the surveillance time interval.

During a surveillance, the margin improvement achievable by implementing a more restrictive RAOC operating space can be easily determined as follows.

Suppose two RAOC Operating Spaces are specified in the COLR as ROS1 and ROS2. From expression (5-3), the percent margin (M) to the F_Q limit can be determined for each ROS as follows:

$$M_{ROS1}(z) = \frac{\frac{CFQ*K(z)}{P_{rel}^{ss}} - [F_Q^W(z)]_{ROS1}}{\frac{CFQ*K(z)}{P_{rel}^{ss}}} * 100\% \qquad for\ P_{rel}^{ss} > 0.5 \qquad (5\text{-}12)$$

$$M_{ROS2}(z) = \frac{\frac{CFQ*K(z)}{P_{rel}^{ss}} - [F_Q^W(z)]_{ROS2}}{\frac{CFQ*K(z)}{P_{rel}^{ss}}} * 100\% \qquad for\ P_{rel}^{ss} > 0.5 \qquad (5\text{-}13)$$

Therefore, the margin improvement for ROS2 relative to ROS1 is simply:

$$M_{ROS2}(z) - M_{ROS1}(z) = \frac{[F_Q^W(z)]_{ROS1} - [F_Q^W(z)]_{ROS2}}{\frac{CFQ*K(z)}{P_{rel}^{ss}}} * 100\% \qquad for\ P_{rel}^{ss} > 0.5 \qquad (5\text{-}14)$$

Using (5-1), this becomes:

$$M_{ROS2}(z) - M_{ROS1}(z) = \frac{\frac{A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F}{P_{rel}^{ss}}}{\frac{CFQ * K(z)}{P_{rel}^{ss}}} * \left\{ [T(z) * R_j]_{ROS1}^{COLR} - [T(z) * R_j]_{ROS2}^{COLR} \right\} * 100\% \qquad for\ P_{rel}^{ss} > 0.5 \qquad (5\text{-}15)$$

After simplification, expression (5-15) becomes:

$$M_{ROS2}(z) - M_{ROS1}(z) = \frac{A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * U_F}{CFQ * K(z)} * \left\{ [T(z) * R_j]_{ROS1}^{COLR} - [T(z) * R_j]_{ROS2}^{COLR} \right\} * 100\% \qquad (5\text{-}16)$$

Because the surveillance power level, P_{rel}^{ss}, cancels out, expression (5-16) is applicable to all surveillance power levels. Expression (5-16) indicates that the margin improvement between two RAOC operating spaces is easily determined from the difference in the applicable $T(z)*R_j$ values.

In a similar way, it is straightforward to show, using (5-1), that the percent change in $F_Q^W(z)$ between two RAOC operating spaces is given by the following:

$$\frac{\left[F_Q^W(z)\right]_{ROS1} - \left[F_Q^W(z)\right]_{ROS2}}{\left[F_Q^W(z)\right]_{ROS1}} * 100\% = 1 - \frac{\left[T(z) * R_j\right]_{ROS2}^{COLR}}{\left[T(z) * R_j\right]_{ROS1}^{COLR}} * 100\% \qquad (5\text{-}17)$$

Consequently, the percent improvement in $F_Q^W(z)$ for two RAOC operating spaces is simply a function of the ratio of the applicable T(z)* R_j values. When $\left[F_Q^W(z)\right]_{ROS1}$ is approximately equal to the F_Q limit, as would be the case if the surveillance challenged the limit, expressions (5-16) and (5-17) will give approximately the same result. In other words, the margin improvement relative to the F_Q limit and the improvement in $F_Q^W(z)$ will be about the same.

6 EXAMPLE APPLICATION OF IMPROVED RAOC F_Q SURVEILLANCE

In this section, the formulation and methods for the Improved RAOC F_Q Surveillance and TS will be applied to a reload core design and an actual surveillance flux map. The core design employed is a typical four-loop, 18 month cycle core design. The same reload core was used for the discussions in Sections 3 and 4. This core is the "Plant A" core in Figure 4-1.

This section will present the RAOC operating spaces chosen for inclusion in the COLR, the analytical transient $F_Q(z)$*Power results for each operating space, the corresponding T(z) functions, the $A_{XY}(z)$ factors for use during a startup surveillance, the R_j factors that account for increases in the transient $F_Q(z)$ between surveillances, and the power level and AFD reduction requirements for Required Action B.2.1. In the last section, the T(z) functions will be employed to determine $F_Q^W(z)$ for an actual BOL flux map.

6.1 RAOC OPERATING SPACES

The choice and number of RAOC operating spaces to be included in the COLR will need to be a subject of discussion at the reload core design initialization meeting conducted for each core design to establish the core design and operational requirements for the next reload cycle. It should only be necessary to include two or three operating spaces in the COLR. Some utilities may opt to include just a single ROS. In this case, if a surveillance shows that $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 would require a reduction in the maximum allowable power as well as a reduction in the AFD limits. These required reductions would be specified in the COLR. The benefit of having multiple ROSs in the COLR is to obviate the need to reduce power by instead reducing the operating space. In this way, the improved F_Q TS is similar to the current F_Q TS.

For this sample analysis, three RAOC operating spaces were analyzed. The operating spaces were chosen to ensure that the two more restrictive operating spaces provided significant margin improvements at all core elevations where transient F_Q margin could possibly be limiting. ROS1 is the "reference" RAOC operating space. ROS2 employs a smaller AFD operating space than ROS1, but the same RILs. ROS3 employs the same smaller AFD operating space as ROS2, but also employs slightly shallower RILs. In terms of minimum transient margin, ROS1 has the least margin while ROS3 has the most. As the following figures show, ROS3 provides margin improvement in the central core region.

Figure 6-1 shows the AFD operating spaces for ROS1, ROS2, and ROS3. The AFD limits for ROS2 and ROS3 are reduced by 5% AFD relative to the ROS1 AFD limits. Figure 6-2 shows the RILs for ROS1 and ROS2. Figure 6-3 gives the ROS3 RILs. The RILs for ROS3 have been raised by 22 steps (about 14 inches) relative to the RILs for ROS1 and ROS2. Each control bank was raised the same number of steps so that the tip-to-tip distance between banks remained the same.

6.2 TRANSIENT $F_Q(Z)$*POWER RESULTS

In a typical RAOC analysis, power shapes are generated at three or four cycle burnups and at three different power levels. For this sample analysis, power shapes were generated at cycle burnups of 150, 4000, 12000, and 20000 MWD/MTU and power levels of 100% RTP, 75% RTP, and 50% RTP.

Figures 6-4 through 6-7 show the maximum transient $F_Q(z)$*Power values calculated at each of the four cycle burnups, respectively, for each of the three operating spaces. As the figures show, ROS2 and ROS3 provide significant margin benefits because of their reduced AFD operating space. ROS3 provides additional benefit in the central core region because of its shallower control bank insertion limits.

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6.3 $[T(Z)]^{COLR}$ VALUES

$[T(z)]^{COLR}$ values were determined for each ROS and each analyzed cycle burnup. The $[T(z)]^{COLR}$ values were calculated from the $[W(z)]^{COLR}$ functions using expression (4-33). Equivalently, expression (4-30) could have been used. Use of expression (4-33) was convenient for this exercise since both the $[W(z)]^{COLR}$ functions and the $[P(z)]^{P}_{Ref}$ power shapes were readily available.

The core models used in this sample analysis did not include explicit modeling of the grids. Consequently, as discussed in Section 4.2, a grid factor was included in the $[T(z)]^{COLR}$ values to account for the small additional power peaking that occurs in the spans between the grids. This factor is not included in the W(z) functions because the grid effects are captured in the measured steady state $F_Q(z)$.

Figures 6-8 through 6-11 give the $[T(z)]^{COLR}$ values for each operating space and, respectively, for each cycle burnup considered. Tabular values are given in Tables 6-1 through 6-4. Note that the $[T(z)]^{COLR}$ values are 0.0 for the top and bottom 8% of the core. These are the exclusion zones selected for this core. The standard 15% top and bottom exclusion zones were not used because the limiting margin location at EOL is at about 12% above the bottom of the active fuel. Verification of $F_Q^W(z)$ is not required in the exclusion zones. The exclusion zones are chosen for the particular core so as to ensure that the limiting margin axial location is surveilled.

6.4 $A_{XY}(Z)$ VALUES FOR INITIAL POWER ASCENSION

As discussed in Section 4.3, the $A_{XY}(z)$ factors adjust the measured $F_{XY}(z)$ for consistency with the reference core conditions used to generate the COLR T(z) values. The vast majority of surveillances are performed at high power conditions during the operating cycle with control rods nearly fully withdrawn. For these surveillances, the $A_{XY}(z)$ will generally be very close to 1.0 at nearly all elevations and, in particular, at elevations where transient F_Q margin is likely to be limiting. Furthermore, for the particular core used in this example, ample transient F_Q margin is anticipated. This is evident from the $F_Q(z)$*Power plots in Figures 6-4 through 6-7. Therefore, an assumption of $A_{XY}(z)$ equal to 1.0 is reasonable.

A convenient method for determining these factors is Method 2 using expression (4-35). In this method, the factors are not included in the COLR. Instead, they are determined for the specific surveillance conditions at the time of the surveillance using an approved 3D core model. In this example analysis, this is the method that will be used.

Section 6.6 will describe the application of this improved F_Q Surveillance formulation to a specific flux map. The flux map was taken at a cycle burnup of 221 MWD/MTU. The core relative power was 0.999, and the D-Bank location was 228 SWD. Table 6-9 gives the $A_{XY}(z)$ values determined using Method 2 and interpolated to the surveillance axial positions. In this case, the flux map was taken at core conditions that are nearly the same as the reference core conditions. Consequently, the $A_{XY}(z)$ values are nearly equal to 1.0 (within about 0.1%), indicating that, for this particular surveillance, essentially no adjustment of the measured radial peaking factors is necessary for consistency with the reference conditions assumed for the COLR T(z) values.

6.5 POWER AND AFD REDUCTIONS

As discussed in Section 5.3, if no ROS included in the COLR provides the required margin improvement when $F_Q^W(z)$ exceeds its limit, then Required Action B.2.1 and the COLR will specify limits on thermal power and required reductions in AFD. Optionally, these reductions may be implemented instead of employing a more restrictive ROS. [

]^{a,c} The minimum margin improvement relative to the reference analysis for that ROS will be determined. The value specified in the COLR will be the minimum margin improvement over the entire operating cycle. Optionally, the COLR may tabulate the margin improvement as a function of cycle burnup.

Table 6-10 gives an example of the kind of information that will appear in the COLR with respect to limits on thermal power and AFD reductions. [

]^{a,c} Similar limits are specified for the other RAOC operating spaces.

The likelihood of any plant being required to reduce power due to $F_Q^W(z)$ exceeding its limit is very remote. If such a situation developed, it would be due to a significant and unanticipated core anomaly or a serious measurement issue. Obviously, any such development would require considerable scrutiny with respect to its nature and future operation. The above power and AFD limits should be viewed as necessary immediate measures to ensure safety limits are met for near term operation.

6.6 TRANSIENT $F_Q(Z)$ MARGIN DECREASE FACTORS

Section 5.5 described the methodology for calculating the R_j factors used to account for decreases in the transient F_Q margin between surveillances. For this example analysis, R_j factors were determined for each ROS throughout the operating cycle using expression (5-9). In generating these factors, an EFPM was conservatively assumed to be equal to 39 EFPD to allow for permissible extensions in the surveillance interval. This is conservative since larger $F_Q^W(z)/K(z)$ increases are possible when a longer time span is assumed until the next surveillance. Tables 6-11 through 6-13 provide the information that would be included in the COLR with respect to these factors for each ROS.

6.7 EXAMPLE FLUX MAP APPLICATION

In this section, the transient $F_Q^W(z)$ margin will be determined for a specific flux map for each ROS using the improved formulation. For comparison, corresponding values using the current F_Q Surveillance formulation will also be determined. The surveillance conditions for the flux map were briefly discussed in Section 6.4. To reiterate, the flux map was taken at a cycle burnup of 221 MWD/MTU with a core relative power of 0.999 and a D-Bank location of 228 SWD. Consequently, the flux map conditions are very close to the reference conditions used in the generating the COLR W(z) and T(z) factors.

Table 6-14 gives the transient $F_Q(z)$ margin results for ROS1 using the current formulation. Here $F_Q^W(z)$ was determined as follows:

$$F_Q^W(z) = W(z) * F_Q^C(z) * R_j = \frac{[W(z)]^{COLR}}{P_{rel}^{SS}} * \left[F_Q(z)\right]_{Surv}^{M} * 1.0815 * R_j \qquad (6\text{-}1)$$

This expression is just expression (3-8) modified using expression (3-15) and including the R_j factor to account for margin decreases between surveillances. The typical 1.0815 value for U_F has been used. The $[W(z)]^{COLR}$ and R_j factors were interpolated to the surveillance cycle burnup. Table 6-14 shows that the minimum margin to the F_Q limit was 10.5% and occurred at an elevation of 2.4 feet.

Table 6-15 gives the corresponding results for the improved formulation. Here, $F_Q^W(z)$ was determined using the following expression:

$$F_Q^W(z) = \frac{[T(z)]^{COLR}}{P_{rel}^{SS}} * A_{XY}(z) * [F_{XY}(z)]_{Surv}^{M} * 1.0815 * R_j \qquad (6\text{-}2)$$

This is just expression (5-1) with 1.0815 used for U_F. As with the current formulation, $[T(z)]^{COLR}$ and R_j were interpolated to the surveillance cycle burnup. The $A_{XY}(z)$ factors are from Table 6-9. As Table 6-15 shows, the minimum margin to the F_Q limit was also 10.5% and occurred at an elevation of 7.4 feet.

Figure 6-12 plots the minimum margin versus elevation for ROS1 for each formulation. Note that, in this case, the minimum margin values for the two formulations are essentially the same. The axial location of the minimum margin, however, is very different for the two formulations. Similar differences occurred for ROS2 and ROS3. The transient F_Q margin results for these operating spaces are shown in Figures 6-13 and 6-14, respectively. These were generated in the same way as in Tables 6-14 and 6-15, but using $[W(z)]^{COLR}$, $[T(z)]^{COLR}$, and R_j factors appropriate for these operating spaces.

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]^{a,c}

For the flux map used in this example, the minimum transient F_Q margin was not very different for the two methods, but the axial location of the minimum margin was very different. If the ΔAO had been larger that 2%, e.g., 4-5%, the margin differences between the two formulations would have been larger as well with the new formulation exhibiting more margin. The new formulation will provide a more accurate assessment of both the magnitude and location of the minimum margin for RAOC plants when there are differences between the measured and predicted axial power shapes.

The effects of the grid depressions are clearly evident in the margin curves for the current method (also in the measured P(z) plot in Figure 6-15). In the current method, the grid depressions are captured via the $\left[F_Q(z)\right]_{Surv}^{M}$ term in expression (6-1). The curves for the improved method do not reflect the grid depressions because the core model used to generate the T(z) factors did not explicitly model the grids. Instead the additional peaking in the spans between the grids was accounted for via a grid factor, which was included in the T(z) values. Future core models may include the grids; therefore, their effects will be directly incorporated into the T(z) factors. In this way, the margin assessment for the improved formulation will also reflect the grid depressions.

Finally, it is important to note the relative margin differences exhibited by the three RAOC operating spaces. [

]a,c

This particular core has ample margin at this surveillance condition for ROS1. If, however, margin were needed, the ROS2 or ROS3 operating spaces would have likely provided sufficient margin improvement to preclude the need for a power reduction.

Table 6-1 $[T(z)]^{COLR}$ Values at 150 MWD/MTU

a,c

Table 6-2 $[T(z)]^{COLR}$ Values at 4000 MWD/MTU

a,c

Table 6-3 $[T(z)]^{COLR}$ Values at 12000 MWD/MTU

a,c

Table 6-4 $[T(z)]^{COLR}$ Values at 20000 MWD/MTU

a,c

Table 6-5 Deleted

Table 6-6 Deleted

Table 6-7 Deleted

Table 6-8 Deleted

Table 6-9 $A_{XY}(z)$ for Specific Flux Map Conditions

a,c

Table 6-10 Required THERMAL POWER Limits and AFD Reductions

a,c

Note:

1. AFD reductions should be applied to both the positive and negative sides of the AFD operating space.

Table 6-11 R_j Margin Decrease Factors for ROS1

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 6-12 R_j Margin Decrease Factors for ROS2

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 6-13 R_j Margin Decrease Factors for ROS3

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 6-14 Surveillance Transient F_Q Margin Assessment for ROS1 – Current Method

a,c

Note:

1. Surveillance relative power level is 0.999.

Table 6-15 Surveillance Transient F_Q Margin Assessment for ROS1 – Improved Method

a,c

[ ]

Note:

1. Surveillance relative power level is 0.999.

a,c

Figure 6-1 RAOC Operating Space (ROS) AFD Limits

a,c

[ ]

Figure 6-2 RAOC Operating Space 1 and 2 Control Bank Insertion Limits

a,c

Figure 6-3 RAOC Operating Space 3 Control Bank Insertion Limits

a,c

Figure 6-4 RAOC Maximum Transient $F_Q(z)$*Power for 150 MWD/MTU

a,c

Figure 6-5 RAOC Maximum Transient $F_Q(z)$*Power for 4000 MWD/MTU

a,c

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Figure 6-6 RAOC Maximum Transient $F_Q(z)$*Power for 12000 MWD/MTU

a,c

Figure 6-7 RAOC Maximum Transient $F_Q(z)$*Power for 20000 MWD/MTU

a,c

Figure 6-8 $[T(z)]^{COLR}$ Factors for 150 MWD/MTU

a,c

Figure 6-9 $[T(z)]^{COLR}$ Factors for 4000 MWD/MTU

a,c

Figure 6-10 $[T(z)]^{COLR}$ Factors for 12000 MWD/MTU

a,c

Figure 6-11 $[T(z)]^{COLR}$ Factors for 20000 MWD/MTU

a,c

Figure 6-12 Surveillance Transient F_Q Margin Assessment for ROS1

a,c

Figure 6-13 Surveillance Transient F_Q Margin Assessment for ROS2

a,c

Figure 6-14 Surveillance Transient F_Q Margin Assessment for ROS3

a,c

Figure 6-15 Measured and Predicted Axial Power Shape Comparison

7 IMPROVED CAOC F_Q SURVEILLANCE FORMULATION

Section 3 discussed the current F_Q Surveillance formulation for RAOC and CAOC plants. This formulation works well for CAOC plants since, as discussed in Section 3.1, the W(z) values are insensitive to differences between measured and predicted axial power shapes. For CAOC plants, the reference conditions used to establish the W(z) values should be the same conditions used to establish the measured target axial offset, i.e., HFP, EQXE, with the lead control bank nearly fully withdrawn. (Often, the CAOC target axial offset is established with the control bank inserted a small amount, e.g., 5-10 steps, to the point where the differential rod worth permits some core reactivity adjustment for inlet temperature control.) Furthermore, when the surveillance is performed, the core conditions should closely correspond to the core conditions that would be used to establish the target axial offset. Under these circumstances, the product of W(z) and the measured $F_Q(z)$ will accurately quantify the postulated maximum transient $F_Q(z)$ for future non-equilibrium CAOC operation about that target AO even if the measured and predicted axial power shapes are not in perfect agreement.

If, however, the surveillance is performed at core conditions that are significantly inconsistent with the conditions used to establish the CAOC target, the resulting transient F_Q margin assessment may not accurately reflect the "true" transient F_Q margin for operation about the "true" target AO. The improved CAOC F_Q Surveillance formulation derived in the following section will include an adjustment factor analogous to the $A_{XY}(z)$ factors in the improved RAOC F_Q Surveillance formulation to adjust the surveillance $F_Q^W(z)$ to the reference conditions used to establish the target AO.

7.1 DERIVATION OF THE IMPROVED CAOC F_Q SURVEILLANCE FORMULATION

From expressions (3-8) through (3-16), the basic equations for the transient $F_Q(z)$ for the current F_Q Surveillance formulation are as follows:

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} * F_Q^C(z) \qquad for\ P_{rel}^{ss} > 0.5 \qquad (7\text{-}1)$$

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{0.5} * F_Q^C(z) \qquad for\ P_{rel}^{ss} \leq 0.5 \qquad (7\text{-}2)$$

where:

[ ]a,c (7-3)

$$F_Q^C(z) = [F_Q(z)]_{Surv}^M * U_F \qquad (7\text{-}4)$$

The limiting conditions for operation are:

$$\frac{CFQ}{P_{rel}^{ss}} * K(z) \geq F_Q^W(z) \qquad for\ P_{rel}^{ss} > 0.5 \tag{7-5}$$

$$\frac{CFQ}{0.5} * K(z) \geq F_Q^W(z) \qquad for\ P_{rel}^{ss} \leq 0.5 \tag{7-6}$$

For the remainder of the derivation, we will assume $P_{rel}^{ss} > 0.5$ and then generalize at the end for all surveillance power levels.

Inserting (7-1) into (7-5) gives the following:

$$\frac{CFQ}{P_{rel}^{ss}} * K(z) \geq \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} * F_Q^C(z) \tag{7-7}$$

Typically, the conditions used to determine the CAOC target AO are HFP, EQXE, and with the lead control bank nearly fully withdrawn. For a given surveillance, suppose that the core conditions during the measurement of $F_Q^C(z)$ are inconsistent with these target AO conditions. In this case, the surveillance $F_Q(z)$ will not be exactly the same as the $F_Q(z)$ that would have been measured had the surveillance been performed at conditions consistent with the natural target. The $F_{XY}(z)$ values will be a little different (probably a little larger). Also, the surveillance P(z) may be somewhat different than the natural target P(z). The W(z) values will correctly account for the increases in P(z) due to transient operation about the surveillance condition, but the surveillance may under- or over-estimate margin if the surveillance P(z) is skewed relative to the natural target P(z). In other words, the W(z) values are valid, but the measured P(z) is not exactly right, i.e., it is not the P(z) that would have been measured at the natural target core conditions.

For example, suppose the surveillance conditions are 75% RTP with D-bank inserted 30 steps and an axial offset that is a few percent more negative than the target axial offset. In this case the measured axial power shape will be more bottom-skewed than the natural target axial power shape. As a consequence, the transient F_Q margin will be slightly smaller in the bottom of the core relative to the margin that would have been measured had the surveillance been performed at the natural target core conditions. For the top of the core, the opposite will be true; the measured margin will likely be larger than would have been measured at the target conditions. Also, because the lead control bank is significantly inserted and the core is at less than RTP, the measured $F_{XY}(z)$ component of $F_Q^C(z)$ will likely be slightly larger than would have been measured at the target conditions. Again, this will reduce margin.

This surveillance can be "adjusted" to the reference core conditions as follows:

[ ]a,c (7-8)

Here, $\left[F_Q(z)\right]^P_{Ref}$ is the predicted $F_Q(z)$ at the reference target AO conditions and $\left[F_Q(z)\right]^P_{Surv}$ is the predicted $F_Q(z)$ at the surveillance conditions. This ratio can be viewed as adjusting the measured $F_Q^C(z)$ to the reference target AO conditions. Alternatively, the ratio can be viewed as adjusting the $[W(z)]^{COLR}$ values to the surveillance condition. Effectively, the product:

[ ]a,c (7-9)

is equal to the W(z) of expression (3-9). [

]a,c

Note that, after this correction, the measured target AO may still disagree with predicted target AO, i.e., the measured P(z) component of $F_Q^C(z)$ may not be the same as the predicted P(z) component of $\left[F_Q(z)\right]^P_{Ref}$. This, however, is acceptable. Capturing the effect of this axial "tilt" is an essential attribute of the CAOC F_Q Surveillance formulation. Similarly, the differences between measured and predicted radial peaking factors will be captured. These differences, however, will be adjusted to be consistent with the target AO core conditions.

For discussion purposes, this adjustment ratio will be referred to as $A_Q(z)$, i.e.,:

[ ]a,c (7-10)

Inserting this into (7-1) and (7-2):

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} * F_Q^C(z) * A_Q(z) \qquad for\ P_{rel}^{ss} > 0.5 \qquad (7\text{-}11)$$

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{0.5} * F_Q^C(z) * A_Q(z) \qquad for\ P_{rel}^{ss} \leq 0.5 \qquad (7\text{-}12)$$

When surveillances are performed at core conditions close to the core conditions corresponding to the target AO measurement, $A_Q(z)$ will be very close to 1.0. This is usually the case.

Expression (7-11) and (7-12) do not include the R_j factor discussed in Section 5.5. This factor accounts for expected increases in $F_Q^W(z)$ between required surveillances. With the inclusion of this factor, (7-11) and (7-12) become:

$$F_Q^W(z) \equiv \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} * F_Q^C(z) * A_Q(z) * R_j \qquad for\ P_{rel}^{ss} > 0.5 \qquad (7\text{-}13)$$

$$F_Q^W(z) \equiv \frac{[W(z)]^{COLR}}{0.5} * F_Q^C(z) * A_Q(z) * R_j \qquad for\ P_{rel}^{ss} \leq 0.5 \qquad (7\text{-}14)$$

Expressions (7-5) and (7-6), the limiting conditions for operation, are unchanged for this improved formulation.

7.2 CALCULATION OF W(Z) FACTORS

For CAOC plants, the general methods for determining the W(z) factors for the COLR are unchanged. References 2, 3, and 4 describe the power shape analyses performed for CAOC plants, which involve simulation of specific load follow scenarios. The load follow scenarios are simply a means of generating representative xenon and power distributions for characterizing non-equilibrium operation within the restricted operating space of CAOC. Part B of Reference 5 describes the calculation of the W(z) factors. Expression (7-3) is used to generate W(z) values for the COLR. For a specific surveillance, these W(z) values are divided by the surveillance power level, as indicated in expressions (7-13) and (7-14), for consistency with the F_Q limit at the surveillance power level.

In determining the W(z) factors (or T(z) factors for RAOC plants), 1D or 3D core models may be used to perform the power shape analyses. In the Westinghouse methodology, the 1D core model currently employed is APOLLO (see WCAP-13524-P-A, "APOLLO - A One Dimensional Neutron Theory Program" [Reference 7]). When 1D core models are used, the axial power shapes are synthesized with predicted $F_{XY}(z)$ values generated using 3D ANC core models; see the following:

- Westinghouse Report WCAP-10965-P-A, "ANC: A Westinghouse Advanced Nodal Computer Code" (Reference 8)
- Westinghouse Report WCAP-11596-P-A, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores" (Reference 9)
- WCAP-16045-P-A, "Qualification of the Two-Dimensional Transport Code PARAGON" (Reference 10)
- WCAP-16045-NP-A Addendum 1-A, "Qualification of the NEXUS Nuclear Data Methodology" (Reference 11)

Alternatively, power shape analyses may be performed using 3D methods, in which case no synthesis is required since the 3D model provides $F_Q(z)$ directly.

While power shape analyses for CAOC plants typically consist of actual load follow simulations, an alternative method is to analyze CAOC operation using the RAOC methods of Reference 5. CAOC power shapes can be determined as combinations of xenon shape, power level, and control bank insertion in the same way that RAOC power shapes are generated. The range of xenon and power shapes considered would simply be limited to those that are achievable and allowable within the more restrictive CAOC AFD operating space.

7.3 CALCULATION OF $A_Q(Z)$ FACTORS

As with the $A_{XY}(z)$ factors described in Section 4.3, the $A_Q(z)$ factors will be unimportant for the vast majority of surveillances. This will be the case since surveillances usually occur at core conditions consistent with or nearly consistent with the conditions used to measure the target AO. Even for most part-power surveillances, the $A_Q(z)$ factors will either be less than 1.0 or close to 1.0 if the axial offset of the core is close to the target AO. Furthermore, part-power surveillances are generally interim surveillances. After the core power is increased to RTP, an additional surveillance is performed at reactor conditions consistent with establishing the target AO.

Calculation of the $A_Q(z)$ factors is analogous to the calculation of $A_{XY}(z)$ discussed in Section 4.3. The methods for determining $A_Q(z)$ are discussed in the following subsections. They are discussed in order of increasing complexity.

7.3.1 Method 1: $A_Q(z)$ is Unity

Setting $A_Q(z)$ to 1.0 is a reasonable option as long as surveillances are performed such that the AO is near the target. This will generally result in $A_Q(z)$ values that are close to 1.0 or less than 1.0. If $A_Q(z)$ is less than 1.0, it is conservative to ignore it. $A_Q(z)$ values greater than 1.0 may occur at some axial locations, but will generally be within 1 or 2 percent of 1.0 for limiting core planes outside of the exclusion zones if the surveillance is performed at a significant power level, e.g., ≥ 90% RTP. If a surveillance is performed at a core power < 90% RTP, the Technical Specification will require another surveillance if core power is increased to 100% RTP.

The next subsection discusses some typical $A_Q(z)$ values for BOL and EOL.

7.3.2 Method 2: Direct Calculation of $A_Q(z)$ for the Surveillance Condition

The most convenient method of determining $A_Q(z)$ is to calculate it at the time of the surveillance using a 3D core model generated using approved methods. Expression (7-10) would be used to calculate the factors as a function of elevation. As an example, Table 7-1 gives BOL and EOL $A_Q(z)$ factors for a surveillance power level of 90% RTP. In each surveillance case, the lead control bank was positioned to match the HFP target axial offset. For BOL, this position was 197 SWD (10.6 ft elevation). For EOL, the bank position was 185 SWD (10.0 ft elevation). The HFP power reference condition has the lead control bank inserted a small amount into the active core region (about 12 steps, elevation 11.1 ft). Equilibrium xenon was assumed at all conditions.

Note that the BOL $A_Q(z)$ values in Table 7-1 are less than or approximately equal to 1.0 except at the ends of the core. The values are influenced by two primary effects: (1) the presence of the control bank in the top of the core, and (2) small differences in the P(z) shapes between the reference and surveillance conditions.

The presence of the control bank in the top of the core suppresses the axial power shape in that region, but also affects the radial peaking factor. For this core, the control bank suppresses $F_{XY}(z)$ at BOL near the top of the core for the surveillance condition. Since both P(z) and $F_{XY}(z)$ are suppressed, the $A_Q(z)$ values are >1.0. The opposite is true at EOL where $F_{XY}(z)$ is considerably increased when the control bank is

inserted. At EOL, $F_{XY}(z)$ is increased more than P(z) is suppressed in the rodded region, resulting in $A_Q(z)$ values less than 1.0. Consequently, the $A_Q(z)$ values are very different at the top of the core for BOL and EOL.

While the axial offsets are the same for the reference and surveillance cases, the P(z) shapes, while very similar, are not exactly the same. Figure 7-1 shows the axial power shapes for the four core conditions of Table 7-1. The subtle differences between the reference and surveillance P(z) shapes influence the $A_Q(z)$ values. In unrodded axial planes where the reference P(z) exceeds the surveillance P(z), the $A_Q(z)$ values will tend to be greater than 1.0.

7.4 CRUD INDUCED POWER SHIFT CONSIDERATIONS FOR CAOC CORES

Section 4.5 discussed CIPS considerations and indicated that the T(z) and W(z) factors can be affected by CIPS. Specifically, CIPS can affect the maximum transient P(z), which appears in the numerator of both the T(z) and W(z) expressions. The recommendations of Section 4.5 apply to CAOC cores. To reiterate, it is proposed that, should CIPS occur, the effect of CIPS on transient F_Q margin should be addressed in a timely fashion, e.g., within several weeks of the observed onset. This is proposed rather than the application of generic CIPS penalty factors that are a function of ΔAO.

Table 7-1 Typical $A_Q(z)$ Factors at BOL and EOL for 90% RTP Surveillances

a,c

Notes:

1. The reference condition is HFP, EQXE, D at 213 SWD. The surveillance condition is 90% RTP, EQXE, D at the position that reproduces the reference condition axial offset.
2. AQ(z) is the ratio of [FQ(z)]RefP and [FQ(z)]SurvP.

a,c

Figure 7-1 P(z) Shapes for Reference (100% RTP) and Surveillance (90% RTP) Core Conditions

8 IMPROVED CAOC F_Q SURVEILLANCE TECHNICAL SPECIFICATION

In this section, the improved CAOC F_Q Surveillance Technical Specification will be discussed. This TS would replace Technical Specification 3.2.1C of Reference 1, "Heat Flux Hot Channel Factor $F_Q(z)$ (CAOC—W(z) Methodology)." In many respects, the improvements in this TS relative to Reference 1 are very similar to the changes previously discussed in Section 5 for the improved RAOC F_Q Surveillance TS. Rather than repeat much of the discussion in Section 5, the reader will be referred to Section 5 when appropriate. The proposed text for the TS and Bases is provided in Appendices D and E, respectively.

8.1 LIMITING CONDITION FOR OPERATION (LCO 3.2.1)

The LCO for the improved version of the CAOC F_Q TS is the same as for the current F_Q TS. It specifies that $F_Q(z)$, as approximated by $F_Q^C(z)$ and $F_Q^W(z)$, shall be within the limits specified in the COLR. As discussed in Section 3.1, $F_Q^C(z)$ is just the equilibrium $F_Q(z)$ at the surveillance condition with appropriate uncertainties included.

From expressions (7-13) and (7-14), $F_Q^W(z)$ is defined as follows:

$$F_Q^W(z) \equiv \frac{[W(z)]^{COLR}}{P_{rel}^{ss}} * F_Q^C(z) * A_Q(z) * R_j \qquad for\ P_{rel}^{ss} > 0.5 \qquad (8\text{-}1)$$

$$F_Q^W(z) \equiv \frac{[W(z)]^{COLR}}{0.5} * F_Q^C(z) * A_Q(z) * R_j \qquad for\ P_{rel}^{ss} \le 0.5 \qquad (8\text{-}2)$$

where:

$$F_Q^C(z) = \left[F_Q(z)\right]_{Surv}^{M} * U_F \qquad (8\text{-}3)$$

As in the RAOC formulation, $F_Q^W(z)$ is the "measured" transient $F_Q(z)$ scaled by the $1/P_{rel}^{ss}$ or 1/0.5 factor from the F_Q limit expression for $P_{rel}^{ss} > 0.5$ and $P_{rel}^{ss} \le 0.5$, respectively.

The F_Q Surveillance limit expressions are the same as for the RAOC TS:

$$\frac{CFQ*K(z)}{P_{rel}^{ss}} \ge F_Q^W(z) \qquad for\ P_{rel}^{ss} > 0.5 \qquad (8\text{-}4)$$

$$\frac{CFQ*K(z)}{0.5} \ge F_Q^W(z) \qquad for\ P_{rel}^{ss} \le 0.5 \qquad (8\text{-}5)$$

$F_Q^C(z)$ and $F_Q^W(z)$ are compared to the same limit, which is a function of power level and is specified in the COLR. This LCO is unchanged in the improved version of the F_Q Technical Specification. Only the definition of $F_Q^W(z)$ has changed through the addition of the $A_Q(z)$ term, which simply serves to adjust the surveillance to the target AO core conditions.

8.2 REQUIRED ACTIONS FOR CONDITION A: $F_Q^C(Z)$ NOT WITHIN LIMIT

When $F_Q^C(z)$ exceeds the limit, the core is in an unanalyzed state following the performance of the Surveillance (SR 3.2.1.1) in that the current peak power density in the core is greater than the maximum value assumed in the safety analyses. The Required Actions and Completion Times for the improved version of the CAOC F_Q TS are the same as for the improved RAOC F_Q TS. When $F_Q^C(z)$ is not within its limit, it is required to do the following:

1. Reduce THERMAL POWER ≥ 1% RTP within 15 minutes for each 1% $F_Q^C(z)$ exceeds the limit (Required Action A.1).

2. Reduce the Power Range Neutron Flux – High trip setpoint (Required Action A.2) by ≥ 1% within 72 hours for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.

3. Reduce the Overpower ΔT trip setpoint (Required Action A.3) by ≥ 1% within 72 hours for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.

4. Perform surveillances on $F_Q^C(z)$ and $F_Q^W(z)$ (Required Action A.4) prior to increasing THERMAL POWER above the limit of Required Action A.1.

These actions were briefly discussed in Section 5.2.

8.3 REQUIRED ACTIONS FOR CONDITION B: $F_Q^W(Z)$ NOT WITHIN LIMIT

The Required Actions for Condition B in the improved CAOC F_Q TS are different relative to the current CAOC F_Q Surveillance TS. If $F_Q^W(z)$ is not within its limit, it will be required to:

1. Within 4 hours, implement a CAOC operating space specified in the COLR that restores $F_Q^W(z)$ to within its limits (Required Action B.1).

   OR

2. Within 4 hours, limit THERMAL POWER to less than RATED THERMAL POWER as specified in the COLR (Required Action B.2.1).

Required Action B.1 permits the implementation of a new CAOC operating space to restore margin if $F_Q^W(z)$ is not within its limit. A CAOC operating space is a unique combination of AFD limits and Control Bank Insertion Limits. The COLR will include one or more CAOC operating spaces. The number of CAOC operating spaces to be included in the COLR will be determined by the utility in conjunction with the core designers. Each CAOC operating space will be pre-analyzed, and W(z) values will be generated for each CAOC operating space and included in the COLR. For the current F_Q TS, a reduction in thermal power is the Required Action if $F_Q^W(z)$ is not within its limit. Implementation of a more restrictive CAOC operating space provides an alternative to a power level reduction. Margin is gained by reducing the operating space. The COLR will contain the necessary information to confirm that the operating space will provide the necessary margin improvement.

The margin and $F_Q^W(z)$ improvement between two CAOC operating spaces can be quantified using the following expressions, which are analogous to expressions (5-16) and (5-17) for RAOC:

$$M_{COS2}(z) - M_{COS1}(z) = \frac{A_Q(z)*F_Q^C(Z)}{CFQ*K(z)} * \left\{\left[W(z) * R_j\right]_{COS1}^{COLR} - \left[W(z) * R_j\right]_{COS2}^{COLR}\right\} \tag{8-6}$$

$$\frac{\left[F_Q^W(z)\right]_{COS1} - \left[F_Q^W(z)\right]_{COS2}}{\left[F_Q^W(z)\right]_{COS1}} * 100\% = 1 - \frac{\left[W(z)*R_j\right]_{COS2}^{COLR}}{\left[W(z)*R_j\right]_{COS1}^{COLR}} * 100\% \tag{8-7}$$

When $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits thermal power to less than RTP by the amount specified in the COLR. If the CAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(z)$ limit, then Required Action B.2.1 must be entered and thermal power must be limited to less than the RTP. (Note that this differs from the improved RAOC F_Q Surveillance TS in that limits on thermal power are also potentially coupled to AFD reductions in the RAOC TS. This would be feasible for CAOC as well. However, AFD limits for CAOC plants are already fairly restrictive and are typically much more restrictive than RAOC plants at reduced power levels. One of the CAOC operating spaces selected for inclusion in the COLR could reflect the narrowest CAOC AFD band that still permits adequate maneuvering and operability as judged by the reactor engineers and operators.)

The required limits on thermal power and the required reductions in the AFD limits for Required Action B.2.1 will be determined using the standard CAOC methodology of References 2, 3, and 4.
[

]^{a,c}

As in the RAOC TS, if Required Action B.2.1 is entered, the improved CAOC F_Q TS also requires the following actions in addition to the two Required Actions listed earlier:

1. Within 72 hours, reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER (Required Action B.2.2).

2. Within 72 hours, reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER (Required Action B.2.3).

3. Prior to increasing THERMAL POWER above the limit of Required Action B.2.1, perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.2.4).

Actions B.2.2 and B.2.3 are consistent with the current F_Q TS and the improved RAOC F_Q TS whenever a reduction in the maximum allowable power is specified. They are conservative measures that provide protection against the consequences of Condition II transients in light of the larger local peaking factors that caused $F_Q^W(z)$ to exceed its limit. Required Action B.2.4 is essentially the same as in the current F_Q TS except that the Completion Time has been specifically tied to Required Action B.2.1, which specifies the required limit on thermal power.

The Required Action for Condition C, "Required Action and Completion Time not met," is unchanged in the improved CAOC F_Q TS. The Required Action is to be in MODE 2 within 6 hours.

8.4 SURVEILLANCE REQUIREMENTS FOR $F_Q^C(Z)$

The Surveillance Requirements for $F_Q^C(z)$ for the improved CAOC F_Q TS are the same as for the improved RAOC F_Q TS. SR 3.2.1.1 requires verification that $F_Q^C(z)$ is within its limit, and the current Frequencies for SR 3.2.1.1 specify that $F_Q^C(z)$ must be verified to be within its limit as follows:

a. Once after each refueling prior to THERMAL POWER exceeding 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

These Frequencies were briefly discussed in Section 5.4 for the improved RAOC F_Q TS.

8.5 SURVEILLANCE REQUIREMENTS FOR $F_Q^W(Z)$

The Surveillance Requirements for $F_Q^W(z)$ for the improved CAOC F_Q TS are the same as for the improved RAOC F_Q TS. These new Frequencies for SR 3.2.1.2 specify that $F_Q^W(z)$ must be verified to be within its limit as follows:

a. Once after each refueling within 24 hours after THERMAL POWER exceeds 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

The discussion provided in Section 5.5 for the improved RAOC F_Q TS applies to the improved CAOC F_Q TS, including the calculation and application of the R_j margin decrease factors. Refer to Section 5.5 for details on these factors.

a,c

Figure 8-1 Typical Standard and Reduced Maximum Power Load Follow Profiles

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9 EXAMPLE APPLICATION OF IMPROVED CAOC F_Q SURVEILLANCE

In this section, the formulation and methods for the improved CAOC F_Q Surveillance TS will be applied to an actual reload core design. This section is analogous to Section 6, which provided an example application of the improved RAOC F_Q Surveillance formulation and TS. The same core design will be employed as in Section 6.

9.1 CAOC OPERATING SPACES

As with the improved RAOC F_Q TS, the choice and number of CAOC operating spaces to be included in the COLR will need to be a subject of discussion at the reload core design initialization meeting conducted for each core design to establish the core design and operational requirements for the next reload cycle. It should only be necessary to include two or three operating spaces in the COLR. Some utilities may opt to include just a single CAOC operating space (COS). In this case, if a surveillance shows that $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 will require that thermal power be limited to less than RTP. The required limit on thermal power will be specified in the COLR. The benefit of having multiple COSs in the COLR is to preclude the need to reduce power by instead reducing the AFD operating band in the unlikely event that $F_Q^W(z)$ exceeds its limit. This is not a feature of the current CAOC F_Q Surveillance TS, i.e., the current F_Q TS (TS 3.2.1C of Reference 1) calls for a reduction in thermal power when $F_Q^W(z)$ exceeds its limit.

For this example application, three CAOC operating spaces were specified and analyzed. The operating spaces were simply chosen as progressively smaller CAOC operating bands. All three COSs use the same control bank insertion limits. Table 9-1 gives the CAOC AFD bands assumed for COS1, COS2, and COS3. [

]^{a,c} Figure 9-1 shows the control bank insertion limits employed.

9.2 CAOC TRANSIENT F_Q(Z)*POWER RESULTS

Figures 9-2 through 9-5 show the maximum transient F_Q(z)*Power values calculated at four cycle burnups for each of the three CAOC operating spaces. The cycle burnups were 150, 4000, 12000, and 20000 MWD/MTU, respectively. As the figures show, COS2 and COS3 provide margin benefits relative to COS1 because of their reduced AFD operating spaces.

9.3 $[W(Z)]^{COLR}$ VALUES

$[W(z)]^{COLR}$ values were determined in the standard manner using expression (7-3) for each COS and for the four cycle burnups listed in Section 9.2. Figures 9-6 through 9-9 give the $[W(z)]^{COLR}$ values for each operating space and, respectively, for each cycle burnup considered. Tabular values are given in Tables 9-2 through 9-5. Note that the $[W(z)]^{COLR}$ values are 1.0 for the top and bottom 8% of the core. These are the exclusion zones chosen for this core. These exclusion zones ensure that the limiting axial location will be surveilled. As Figure 9-5 shows, the minimum margin location is at about 1.4 ft near EOL, which correspond to 12% of the core height.

9.4 A_Q(Z) VALUES

The $A_Q(z)$ factors adjust the surveillance for consistency with the reference core conditions for measuring the target AO. For the purposes of this example application, it will be assumed that explicit $A_Q(z)$ values are not included in COLR. Rather, values will be determined for each surveillance using an approved core model. This is Method 2 discussed in subsection 7.3.2.

Section 9.7 will describe the application of this formulation to a specific flux map. This is the same flux map used in Section 6.7. The flux map was taken at a cycle burnup of 221 MWD/MTU. The core relative power was 0.999, and the D-Bank location was 228 SWD. Table 9-6 gives the $A_Q(z)$ values determined using Method 2 and expression (7-10) and interpolated to the surveillance axial positions. The core conditions for the flux map are very similar to the reference core conditions assumed for the target measurement. These reference conditions are a relative power of 1.0, EQXE, and D-Bank at 213 steps. This was the reference condition used to generate the steady-state $F_Q(z)$ for the W(z) factors, specifically, the denominator of expression (7-3). It was also the reference condition for establishing the target AO in the CAOC simulations. As Table 9-6 shows, the $A_Q(z)$ values are reasonably close to 1.0. The largest $A_Q(z)$ value is 1.014 near the bottom of the core. This occurs since the reference condition includes a small amount of control bank insertion, resulting in a predicted target AO that is slightly more negative than the predicted AO at the surveillance conditions.

9.5 POWER REDUCTIONS

As discussed in Section 8.3, if no COS included in the COLR provides the required margin improvement when $F_Q^W(z)$ exceeds its limit, then Required Action B.2.1 and the COLR will specify limits on thermal power. Optionally, this limit on thermal power may be implemented instead of employing a more restrictive COS. [

]a,c

Table 9-7 gives the expected margin improvement for each COS when thermal power is limited to 95% RTP and 90% RTP. [

]a,c

As with RAOC operation, the likelihood of any plant being required to reduce power due to $F_Q^W(z)$ exceeding its limit is very remote. If this situation occurred, it would be due to a very large and unanticipated core anomaly or a serious measurement issue which would require considerable scrutiny with respect to its nature and with respect to future operation. The thermal power limits that will be specified in the COLR should be viewed as necessary short term measures to ensure that safety limits are met for near term operation.

9.6 TRANSIENT $F_Q(Z)$ MARGIN DECREASE FACTORS

Section 5.5 described the methodology for calculating the R_j factors used to account for expected decreases in the transient F_Q margin between surveillances. For this example analysis, R_j factors were determined for each COS throughout the operating cycle using expression (5-9). Tables 9-8 through 9-10 provide the information that would be included in the COLR with respect to these factors for each respective COS.

9.7 EXAMPLE FLUX MAP APPLICATION

In this section, the transient $F_Q^W(z)$ margin will be determined for a specific flux map for each COS using the improved formulation. For comparison, corresponding values using the current F_Q Surveillance formulation will also be determined. The only real difference between the current formulation and improved formulation for CAOC is the $A_Q(z)$ term. The flux map core conditions are those discussed previously. Specifically, the flux map was taken at a cycle burnup of 221 MWD/MTU with a core relative power of 0.999 and a D-Bank location of 228 SWD. For this example application, the Target AO core conditions assumed were a core relative power of 1.0 and a D-Bank location of 213 SWD.

Table 9-11 gives the transient $F_Q(z)$ margin results for COS1 using the current formulation. Here $F_Q^W(z)$ was determined using expression (6-1), which is repeated here:

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{P_{rel}^{SS}} * F_Q^C(z) * R_j \tag{9-1}$$

The $[W(z)]^{COLR}$ and R_j factors were interpolated to the surveillance cycle burnup of 221 MWD/MTU. Table 9-11 shows that the minimum margin to the F_Q limit was 12.5 % and occurred at an elevation of 3.4 feet.

Table 9-12 gives the corresponding results for the improved formulation. Here, $F_Q^W(z)$ was determined using the following expression:

$$F_Q^W(z) = \frac{[W(z)]^{COLR}}{P_{rel}^{SS}} * F_Q^C(z) * A_Q(z) * R_j \tag{9-2}$$

This is just expression (8-1) and differs from expression (9-1) only by the inclusion of the $A_Q(z)$ term. The $A_Q(z)$ factors in Table 9-12 are from Table 9-6. As Table 9-12 shows, the minimum margin to the F_Q limit was 11.5 % and occurred at an elevation of 3.4 feet.

Figure 9-10 plots the minimum margin versus elevation for COS1 for the current and improved formulations. The calculations in Tables 9-11 and 9-12 were repeated for COS2 and COS3. The margin comparisons are given in Figures 9-11 and 9-12 for COS2 and COS3, respectively.

These figures illustrate how the expected minimum margin improves when the CAOC AFD band is reduced through implementation of a more restrictive COS. COS2 provides a margin benefit of about 1.7% relative to COS1. COS3 provides a 4.2% benefit relative to COS1.

This particular core has significant margin to the limit at this surveillance condition. If, however, margin were needed, these operating spaces would have very likely provided sufficient margin improvement to preclude the need for a power reduction.

Finally, the differences between the current and improved formulations with respect to minimum margin were 1.0%, 0.8%, and 0.7% for COS1, COS2, and COS3, respectively. These small differences are entirely due to the Target AO core conditions chosen for this example and the resulting values of $A_Q(z)$. If the Target AO core condition had assumed a D-Bank position of 228 SWD, as in the surveillance, the $A_Q(z)$ values would have essentially been equal to 1.0, and the differences between the current and improved formulations would have been negligible. This example simply illustrates the effect that small differences in the Target AO and steady-state P(z) can have on the minimum margin for CAOC plants. The W(z) values are not affected by these differences since they are primarily a function of the width of the CAOC AFD band. When the target AO core conditions yield a slightly more skewed AO and P(z), the result can be slightly less margin.

Table 9-1 AFD Bands for CAOC Operating Spaces

a,c

Table 9-2 $[W(z)]^{COLR}$ Values at 150 MWD/MTU

a,c

Table 9-3 $[W(z)]^{COLR}$ Values at 4000 MWD/MTU

a,c

Table 9-4 $[W(z)]^{COLR}$ Values at 12000 MWD/MTU

a,c

Table 9-5 $[W(z)]^{COLR}$ Values at 20000 MWD/MTU

a,c

Table 9-6 $A_Q(z)$ for Specific Flux Map Conditions

a,c

Table 9-7 Required THERMAL POWER Limits

a,c

Table 9-8 R_j Margin Decrease Factors for COS1

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 9-9 R_j Margin Decrease Factors for COS2

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 9-10 R_j Margin Decrease Factors for COS3

a,c

Values may be interpolated to the surveillance cycle burnup.

Table 9-11 Surveillance Transient F_Q Margin Assessment for COS1 – Current Method

a,c

Table 9-12 Surveillance Transient F_Q Margin Assessment for COS1 – Improved Method

a,c

a,c

Figure 9-1 Control Bank Insertion Limits for CAOC Operating Spaces

a,c

[ ]

Figure 9-2 CAOC Maximum Transient $F_Q(z)$*Power for 150 MWD/MTU

a,c

[ ]

Figure 9-3 CAOC Maximum Transient $F_Q(z)$*Power for 4000 MWD/MTU

a,c

[redacted]

Figure 9-4 CAOC Maximum Transient $F_Q(z)$*Power for 12000 MWD/MTU

a,c

Figure 9-5 CAOC Maximum Transient $F_Q(z)$*Power for 20000 MWD/MTU

a,c

Figure 9-6 [W(z)]^{COLR} Factors for 150 MWD/MTU

a,c

Figure 9-7 [W(z)]^{COLR} Factors for 4000 MWD/MTU

a,c

Figure 9-8 $[W(z)]^{COLR}$ Factors for 12000 MWD/MTU

a,c

[ ]

Figure 9-9 $[W(z)]^{COLR}$ Factors for 20000 MWD/MTU

a,c

Figure 9-10 Surveillance Transient F_Q Margin Assessment for COS1

a,c

Figure 9-11 Surveillance Transient F_Q Margin Assessment for COS2

a,c

Figure 9-12 Surveillance Transient F_Q Margin Assessment for COS3

10 IMPLEMENTATION

As discussed in Section 1.1, the improved F_Q Technical Specifications provided in the appendices were developed using the current F_Q Technical Specifications of Reference 1 as a basis. While current plant TS generally reflect the key attributes of these current F_Q TS, a cursory review of actual plant Technical Specifications will quickly reveal a substantial amount of variability. These variations reflect, for example, different capabilities with respect to core monitoring or additional options for addressing F_Q limit violations. As discussed in the following sections, a significant number of Westinghouse plants have implemented the BEACON Core Monitoring System (Reference 12). This system can be used in a variety of ways to monitor the reactor core power distribution. In one variation, the calibrated BEACON core model is used to perform the required periodic surveillances instead of the flux mapping system. This model essentially provides the measured core power distribution directly. Another variation example is the use of baseload TS. A few plants include a baseload option in their TS that permits the use of a very narrow AFD CAOC operating space as an option to the wider RAOC AFD envelope. In a very real sense, this variation is analogous to the improved F_Q TS in that it provides an option for implementing a reduced operating space as a means of gaining margin.

For those plants whose current TS closely follow the TS of Reference 1, implementation of the improved F_Q TS should be straightforward. For plants with variations, some modifications to the improved F_Q TS may be desirable. The intent of this section is not to discuss each plant-specific variation of the F_Q Surveillance Technical Specifications. Rather, the intent is to generally discuss some of the major variations with respect to how individual utilities may opt to implement these improved F_Q TS within the context of their current surveillance methodologies and procedures. Each of the following sections briefly discusses one such variation.

10.1 DIRECT MARGIN MONITORING PLANTS

A small number of Westinghouse NSSS plants employ the BEACON Core Monitoring System to perform continuous and direct margin monitoring of key safety parameters, including the peak local power density. For these plants, the BEACON model is calibrated to the measured core using thermocouple data, excore detector data, and periodic flux map data. Calibration can also be performed using fixed incore detector data, if available. This system has great advantages since, for example, it eliminates the need for periodic surveillance of a number of power distribution related limits (e.g., AFD, Quadrant Power Tilt, $F_{\Delta H}$, and F_Q) unless the Power Distribution Monitoring System (PDMS) is out of service (a very rare event). For plants that do not employ continuous margin monitoring, surveillance of LCO parameters like AFD is needed to ensure that the conclusions of the safety analyses remain valid when the core is operated in a non-equilibrium mode. These analyses make assumptions with respect to the power shape limits, and the core must be operated within those limits for the analyses to remain valid. With continuous monitoring, key LCO limits are confirmed in real time and without the need for analytical penalty factors such as W(z) or T(z), which account for the potential effects of future non-equilibrium operation relative to baseload operation. For these plants, it is unnecessary to penalize the core for aggressive future non-equilibrium operation that may never occur. Whether in equilibrium or non-equilibrium operating mode, the current core state is always being monitored and assessed relative to key safety limits.

For this category of plants, the improved F_Q Technical Specifications of the appendices are only relevant when PDMS is out of service. In this unlikely event, periodic surveillance of $F_Q^C(z)$ and $F_Q^W(z)$ can be performed in the manner outlined in the improved F_Q TS. The current Required Actions and Surveillance Requirements can be modified in a straightforward manner to be consistent with the recommended Required Actions and Surveillance Requirements in the appendices. The COLR for these cores can specify one or more operating spaces and can contain the necessary information to perform periodic surveillances of the core while PDMS is out of service.

10.2 TECHNICAL SPECIFICATION MARGIN MONITORING PLANTS

Another category of plants uses the BEACON Core Monitoring System as part of the PDMS to periodically verify LCO limits. For these plants, the PDMS is employed instead of flux maps to monitor key limits, like $F_Q^C(z)$ and $F_Q^W(z)$, according to the standard surveillance Frequencies, e.g., every 31 EFPD. The BEACON core model is continuously calibrated to the core as in the direct margin monitoring plants described is Section 10.1. As such, the BEACON core power distribution is essentially the measured core power distribution. This system has an important advantage relative to flux mapping in that, once the BEACON model is calibrated to the core, the BEACON core model can be taken to the appropriate surveillance conditions (e.g., ARO, HFP, EQXE) to perform a surveillance. Consequently, the difficulties of part-power surveillances are avoided. Thus, the $F_Q^W(z)$ surveillance will always be consistent with the core conditions that serve as the basis for the COLR W(z) or T(z) factors. Consequently, the $A_{XY}(z)$ and $A_Q(z)$ factors become irrelevant (essentially, they are equal to 1.0).

Again, implementation of the improved F_Q Technical Specifications for these plants should be straightforward. The PDMS simply replaces the traditional flux map as a means of determining the measured core power distribution. The Required Actions and Surveillance Requirements can be updated to be consistent with the improved F_Q TS. For these plants, the uncertainties applied to the BEACON power distribution are determined using the methodology of Reference 12. When PDMS is out of service, standard uncertainties are used. This is currently discussed in the Bases for these plants, and this text can be carried forward when an improved F_Q TS is implemented.

10.3 CAOC F_{XY} SURVEILLANCE PLANTS

A small number of plants currently employ the CAOC operating strategy in conjunction with F_{XY} Surveillance methodology (TS 3.2.1A of Reference 1). This F_{XY} Surveillance methodology used in conjunction with CAOC operation has similar difficulties as the current F_Q Surveillance methodology used in conjunction with RAOC operation.

The F_{XY} limits for these plants are a function of the margin between the $F_Q(z)$ limit and the predicted transient $F_Q(z)$ determined using the CAOC power shape analysis methodology. The transient $F_Q(z)$, however, is a function of the baseload axial power shape at the target AO core conditions. This was illustrated in Figure 3-1. If the measured baseload axial power shape differs significantly from the predicted baseload axial power shape, the transient $F_Q(z)$ will be affected. In the half of the core where the measured power is larger, the transient $F_Q(z)$ will be commensurately larger. In the half of the core where the measured power is smaller, the transient $F_Q(z)$ will be commensurately smaller. Consequently, the F_{XY} limits are sensitive to differences between the measured and predicted axial power distributions in the

same way that W(z) factors are sensitive to these differences for RAOC plants (but not CAOC plants). F_{XY} limits should be adjusted if these differences are significant.

The CAOC F_Q Surveillance formulation avoids this problem through the use of W(z) factors, which are insensitive to measured and predicted axial power distribution differences for CAOC plants. The W(z) factors are primarily a function of the width of the CAOC AFD band. Similarly, the improved RAOC F_Q Surveillance formulation avoids this problem because the T(z) factors are insensitive to measured and predicted axial power distribution differences. Measured $F_{XY}(z)$ is used instead of measured $F_Q(z)$ in the RAOC formulation. Consequently, the formulation is insensitive to the measured axial power shape at the surveillance condition.

Therefore, implementation of either the improved CAOC or the improved RAOC F_Q TS is recommended for CAOC plants currently using F_{XY} Surveillance.

10.4 PLANTS WITH A BASELOAD CAOC OPERATING SPACE OPTION

Several RAOC plants include a baseload option in their AFD and F_Q TS which permits operation within a narrow CAOC band. The width of the baseload CAOC band is specified in the COLR. Such operation provides a considerable margin benefit at the cost of a significantly reduced operating space.

If desired, this kind of operating space option could be readily implemented within the context of the improved F_Q Technical Specifications. As delineated in Appendix A, the improved RAOC F_Q Surveillance TS Required Action B.1 calls for implementation of a RAOC Operating Space that restores $F_Q^W(z)$ to within its limits when Condition B is entered. There is no reason, however, to limit operating space options to RAOC. The Required Action could, instead, call for implementation of a RAOC or CAOC operating space that restores $F_Q^W(z)$ to within its limits. In this case, the TS would be a synthesis of the CAOC and RAOC improved F_Q Technical Specifications. The AFD TS would also need to reflect the potential for CAOC or RAOC operation. Similarly, the bases would need to reflect both kinds of operating strategies. COLR W(z) values would be required for any CAOC operating spaces specified in the COLR.

Use of a narrow CAOC operating space as a backup operating strategy to RAOC is already being done at these plants and is clearly a viable variation for plants which desire to retain this option or to implement it for the first time.

10.5 UTILITY-SPECIFIC METHODOLOGIES AND TECHNICAL SPECIFICATIONS

Some utilities have developed and licensed their own power shape analysis methodologies that are similar to the approved Westinghouse power shape analysis methodologies. In addition, some have implemented TSs which, while different from the current F_Q TS of Reference 1, are functionally equivalent. These utilities can implement the improvements discussed in this report by incorporating the essential attributes of the transient $F_Q(z)$ formulations within the context of their own power shape analysis methodologies and TSs. The key essential attributes of the improved RAOC F_Q Surveillance formulation are the T(z) parameter and the use of measured $F_{XY}(z)$. [

]^{a,c} The product of T(z) and the measured steady-state $F_{XY}(z)$, therefore, provides an estimate of the postulated maximum

transient $F_Q(z)$. Any approved power shape analysis methodology can be used to determine T(z) or, equivalently, predict the maximum transient $F_Q(z)$ and the $F_{XY}(z)$ at the surveillance condition. These analytical parameters can then be used in conjunction with the measured $F_{XY}(z)$ to determine the "measured" maximum transient $F_Q(z)$. Similarly, alternative power shape analysis methodologies can be used to determine W(z) values for CAOC plants, which can be used in conjunction with the measured steady-state $F_Q(z)$ to determined the "measured" transient $F_Q(z)$.

Also, it is important to note that some utilities with in-house analysis capabilities may opt to determine the T(z) or W(z) values at the time of the surveillance rather than including pre-calculated values in the COLR. This should be a viable alternative as long as approved methodologies are used to determine the factors. In reality, the T(z) and W(z) factors are not core operating limits per se; they are analytical factors that characterize transient behavior and facilitate estimates of $F_Q(z)$ for future non-equilibrium operation. Including them in the COLR is primarily a convenient way of capturing and transmitting them together with the actual LCO limits. Calculation of these factors at the time of the surveillance has some advantages in that core models which reflect the actual history of the operating cycle and the actual surveillance condition can be used to determine the appropriate surveillance-specific factors.

11 SUMMARY AND CONCLUSION

The purpose of the F_Q Surveillance Technical Specification is to provide assurance that the heat flux hot channel factor, F_Q, will remain within the limits assumed in the plant safety analyses when the core is operated within its allowed operating space. This report has presented new formulations for RAOC and CAOC F_Q Surveillance and improved RAOC and CAOC F_Q Surveillance TSs. The new formulations and improved F_Q TSs will provide more accurate assessments of transient $F_Q(z)$ margin as well as new options for modifying the core operating space when a surveillance indicates that transient $F_Q(z)$ could exceed its limit during future non-equilibrium operation.

For RAOC, the new formulation is significantly different than the current formulation. It employs measured $F_{XY}(z)$ instead of measured $F_Q(z)$. It utilizes a new analytical factor, T(z), that characterizes transient behavior in a slightly different way than W(z). [

]^{a,c}

The current F_Q Surveillance formulation works well for CAOC plants, where the allowed deviation of the AFD about the natural HFP target AFD is fixed. [

]^{a,c} This adjustment factor will usually be close to 1.0 in the usual case where the surveillance is performed at or near the Target AO core conditions.

The improved RAOC F_Q Surveillance TS addresses an important shortcoming with respect to the current RAOC F_Q Surveillance TS Required Actions. Required Action B.1 in the current F_Q RAOC TS stipulates a reduction in the RAOC AFD envelope of $\geq$ 1% for each 1% that $F_Q(z)$ exceeds its limit. This Required Action, however, does not adequately restore F_Q margin in all circumstances. Specifically, if the F_Q limit is exceeded in the central core region, reducing the AFD envelope by a small amount will likely not restore the required margin. To address this, the improved RAOC F_Q Surveillance TS incorporates the concept of RAOC operating spaces. A RAOC operating space (ROS) is a unique combination of Control Bank Insertion Limits and AFD limits. In the improved F_Q TS, T(z) factors are pre-calculated for multiple RAOC operating space assumptions. The RAOC operating spaces and T(z) factors are specified in the COLR. If the F_Q limit is exceeded during a surveillance, a more restrictive RAOC operating space can be

implemented for future operation that provides the required additional transient F_Q margin. In the unlikely event that no RAOC operating space provides the required margin improvement, then thermal power and AFD restrictions defined in the COLR are required.

The improved CAOC F_Q Surveillance TS also incorporates the concept of operating spaces. The current CAOC F_Q Surveillance TS requires a power level reduction if the F_Q limit is exceeded. The improved F_Q TS provides the option of implementing a more restrictive CAOC operating space, which is defined as a unique combination of AFD band and Control Bank Insertion Limits. As in the improved RAOC F_Q Surveillance TS, the CAOC operating spaces are specified in the COLR.

Both the improved RAOC and CAOC F_Q Surveillance TSs modify the surveillance Frequencies of the TS by requiring that the first surveillance of $F_Q^W(z)$ following a refueling be performed after exceeding 75% RTP. Performing this initial verification after exceeding 75% RTP ensures that the surveillance will be performed with the more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium operation could be limiting. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

Finally, a minor improvement was made to the manner in which potential decreases in the transient F_Q margin between surveillances are addressed. In the improved F_Q TS, application of an $F_Q^W(z)$ penalty factor included in the COLR will be required regardless of the previous measurement trend. When margin is predicted to decrease, the COLR will indicate a penalty factor that is greater than 1.0. If margin is predicted to increase, no penalty is required (the COLR penalty factor is 1.0). Thus, the application of the penalty factor is tied to a predicted decrease in the actual transient F_Q margin in the upcoming surveillance period rather than an increase in the measured value of $F_Q^C(z)/K(z)$ over the previous surveillance period. This is more appropriate and rigorous since future decreases in margin are the relevant concern.

It is anticipated that implementation of these new formulations and TSs will lead to more accurate transient F_Q margin assessments and more appropriate compensatory measures in the unlikely event that limits are exceeded.

12 REFERENCES

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APPENDIX A
IMPROVED RAOC F_Q SURVEILLANCE TS

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
3.2.1B

3.2 POWER DISTRIBUTION LIMITS

T

3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)

LCO 3.2.1B $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered. ------------------------------- $F_Q^C(Z)$ not within limit. prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.	A.1	Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	<u>AND</u>		
	A.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% ~~$F_Q^C(Z)$ exceeds limit~~.	72 hours after each $F_Q^C(Z)$ determination that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.
	<u>AND</u>		
	A.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% ~~$F_Q^C(Z)$ exceeds limit~~.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>		
	A.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

OR
B.2.1 ————NOTE————
Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1.
————————
Limit THERMAL POWER to less than RATED THERMAL POWER and reduce AFD limits as specified in the COLR.

Implement a RAOC operating space specified in the COLR that restores $F_Q^W(z)$ to within its limits.
AND
B.1.2 Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
3.2.1B

CONDITION	REQUIRED ACTION		COMPLETION TIME
B. ~~——NOTE—— Required Action B.4 shall be completed whenever this Condition is entered. ——~~ $F_Q^W(Z)$ not within limits.	B.1 .1	~~Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit.~~	4 hours 72 hours 4 hours
	AND		
	B.2 2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% that ~~the maximum allowable power of the AFD limits is reduced.~~ THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1.	72 hours
	AND		
	B.~~3~~ 2.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that ~~the maximum allowable power of the AFD limits is reduced.~~	72 hours
	AND		
	B.~~4~~ 2.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the ~~maximum allowable power of the AFD limits~~ limit of Required Action B.2.1
C. Required Action and associated Completion Time not met.	C.1	Be in MODE 2.	6 hours

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
3.2.1B

SURVEILLANCE REQUIREMENTS

~~-NOTE-~~
~~During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.~~

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP AND Once within [~~12~~ 24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified AND [31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
3.2.1B

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	~~------NOTE------~~ ~~If measurements indicate that the~~ ~~maximum over z [$F_Q^C(Z)$ / K(Z)]~~ ~~has increased since the previous evaluation of $F_Q^C(Z)$:~~ ~~a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or~~ ~~b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the~~ ~~maximum over z [$F_Q^C(Z)$ / K(Z)]~~ ~~has not increased.~~ ~~------------~~	within [24] hours after thermal power exceeds 75% RTP
	Verify $F_Q^W(Z)$ is within limit.	Once after each refueling ~~prior to THERMAL POWER exceeding 75% RTP~~ AND 24 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 AND

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
3.2.1B

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

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APPENDIX B
IMPROVED RAOC F_Q SURVEILLANCE TECHNICAL SPECIFICATION BASES

T

$F_Q(Z)$ (RAOC-~~W~~T(Z) Methodology)
B 3.2.1B

B 3.2 POWER DISTRIBUTION LIMITS

T

B 3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-~~W~~T(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO(QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents an equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, ~~the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.~~

the elevation dependent measured planar radial peaking factors, $F_{XY}(z)$, are increased by an elevation dependent factor, $[T(z)]^{COLR}$, that accounts for the expected maximum values of the transient axial power shapes postulated to occur during RAOC operation. Thus, $[T(z)]^{COLR}$ accounts for the worst case non-equilibrium power shapes that are expected for the assumed RAOC operating space.

The RAOC operating space is defined as the combination of AFD and Control Bank Insertion Limits assumed in the calculation of a particular $[T(z)]^{COLR}$ function. The $[T(z)]^{COLR}$ factors are directly dependent on the AFD and Control Bank Insertion Limit assumptions. The COLR may contain different $[T(z)]^{COLR}$ functions that reflect different operating space assumptions. If the limit on $F_Q(z)$ is exceeded, a more restrictive operating space may be implemented to gain margin for future non-equilibrium operation.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$F_Q(Z) \le (CFQ / P)\ K(Z)$ for $P > 0.5$

$F_Q(Z) \le (CFQ / 0.5)\ K(Z)$ for $P \le 0.5$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized FQ(Z) limit as a function of core height provided in the COLR, and

P = THERMAL POWER / RTP

T

$F_Q(Z)$ (RAOC-~~W(Z)~~ Methodology)
B 3.2.1B

BASES

LCO (continued)

2.50

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of ~~[2.32]~~, and K(Z) is a function that looks like the one provided in Figure B 3.2.1B-1.

For Relaxed Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

The expression for $F_Q^W(Z)$ is:

$$F_{XY}^M(z)\ \frac{\underline{[T(z)]^{COLR}}}{P}\ A_{XY}(z)\ Rj\ [1.0815]$$

$$F_Q^W(Z) = \cancel{F_Q^C(Z)\,W(Z)}$$

INSERT 1
(next page)

~~where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.~~

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

Violating the LCO limits for $F_Q(z)$ could result in unacceptable consequences if a design basis event were to occur while $F_Q(z)$ exceeds its specified limits.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required and if $F_Q^W(Z)$ cannot be maintained within the LCO limits, ~~reduction of the AFD limits is required. Note that sufficient reduction of the AFD limits will also result in a reduction of the core power.~~

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a more restrictive RAOC operating space must be implemented or core power limits and AFD limits must be reduced.

~~Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.~~

$A_{XY}(z)$ is a function that adjusts the $F_Q^W(z)$ Surveillance for differences between the reference core condition assumed in generating the $[T(z)]^{COLR}$ function and the actual core condition that exists when the Surveillance is performed.

Revised INSERT #1 for Bases B 3.2.1B

The various factors in this expression are defined below:

$F_{XY}^M(z)$ is the measured radial peaking factor at axial location z and is equal to the value of $F_Q^M(z)/P^M(z)$, where $P^M(z)$ is the measured core average axial power shape.

$[T(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[T(z)]^{COLR}$ functions are specified for each analyzed RAOC operating space (i.e., each unique combination of AFD limits and Control Bank Insertion Limits). The $[T(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each RAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[T(z)]^{COLR}$. The $[T(z)]^{COLR}$ functions also account for the following effects: (1) the presence of spacer grids in the fuel assembly, (2) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (3) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (4) the increase in radial peaking due to non-equilibrium xenon effects. The $[T(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at nominal RTP conditions with all shutdown and control rods fully withdrawn, i.e., all rods out (ARO). Surveillance specific $[T(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

100% RTP, all rods out, and equilibrium xenon.

~~$A_{XY}(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_{XY}^M(z)$ to the reference core conditions assumed in generating the $[T(z)]^{COLR}$ factors.~~ Normally, this reference core condition is ~~HFP, ARO, EQXE~~. For simplicity, $A_{XY}(z)$ may be assumed to be ~~1.0. If, however, margin is needed for a Surveillance performed at conditions different from the reference core conditions, then the appropriate values for $A_{XY}(z)$ may be used. Sub-factors of $A_{XY}(z)$ may also be determined and included in the COLR. These sub factors are $F_{PC}(z)$ and $F_{RC}(z)$. $F_{PC}(z)$ is a factor that adjusts the measured $F_{XY}^M(z)$ to the reference core power (typically RTP) if the Surveillance is performed at part power conditions. $F_{RC}(z)$ is a factor that adjusts the measured $F_{XY}^M(z)$ values to the reference rodded condition (typically ARO) if the surveillance condition includes insertion of the lead control bank. When these sub factors are used, $A_{XY}(z)$ is the product of $F_{PC}(z)$ and $F_{RC}(z)$.~~

[1.0815] is a factor that accounts for fuel manufacturing tolerances and measurement uncertainty.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each RAOC operating space.

~~REVIEWER'S NOTE~~

~~WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~

1.0, as this will typically result in an accurate $F_Q^W(z)$ Surveillance result for a Surveillance that is performed at or near the reference core condition, and an underestimation of the available margin to the F_Q limit for Surveillances that are performed at core conditions different from the reference condition. Alternatively, the $A_{XY}(z)$ function may be calculated using the NRC approved methodology in Reference 6.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% ~~by which $F_Q^C(Z)$ exceeds its limit,~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1 is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux - High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux - High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux - High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux - High trip setpoints.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

ACTIONS (continued)

that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by ≥ 1% for each 1% ~~by which $F_Q^C(Z)$ exceeds its limit,~~ is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1~~,~~ ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

prior to increasing THERMAL POWER above the limit of Required Action A.1. The Note also states that SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 (if required) will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

B.1 1

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. ~~Reducing the AFD by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, restricts the axial flux distribution such that even if a transient occurred, core peaking factors are not exceeded.~~

Implementing a more restrictive RAOC operating space, as specified in the COLR, within the allowed Completion Time of 4 hours will restrict the AFD such that peaking factor limits will not be exceeded during non-equilibrium normal operation. Several RAOC operating spaces, representing successively smaller AFD envelopes and, optionally, shallower Control Bank Insertion Limits, may be specified in the COLR. The corresponding T(z) functions for these operating spaces can be used to determine which RAOC operating space will result in acceptable non-equilibrium operation within the $F_Q^W(z)$ limit.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

ACTIONS (continued)

~~The implicit assumption is that if W(Z) values were recalculated (consistent with the reduced AFD limits), then $F_Q^C(Z)$ times the recalculated W(Z) values would meet the $F_Q(Z)$ limit. Note that complying with this action (of reducing AFD limits) may also result in a power reduction. Hence the need for Required Actions B.2, B.3 and B.4.~~

INSERT 2 (Next Page)

B.~~2~~ 2

the

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% by which the maximum allowable power is reduced~~,~~ is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER ~~as a result of reducing~~ AFD limits in accordance with Required Action B.~~1~~.

2.1 limit and

B.~~3~~ 2.3

the

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% by which the maximum allowable power is reduced~~,~~ is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER ~~as a result of reducing~~ AFD limits in accordance with Required Action B.~~1~~.

limit and

2.1

2.4

B.~~4~~

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the maximum allowable power limit imposed by Required Action B.~~1~~ ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

2.1

~~Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.~~

INSERT 2

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new RAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new RAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new RAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(Z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(Z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

The Completion Time of 4 hours provides an acceptable time to reduce the THERMAL POWER and AFD limits in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(Z)$ and would require power reductions within 4 hours of the $F_Q^W(Z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(Z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

T

$F_Q(Z)$ (RAOC-W(Z) Methodology)
B 3.2.1B

BASES

ACTIONS (continued)

2.4

C.1

If Required Actions A.1 through A.4 or B.1 through B.4 are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

some determination of $F_Q^C(Z)$ is made prior to achieving a significant power level where the peak linear heat rate could approach the limits assumed in the safety analyses.

following a refueling

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that ~~the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.~~

initial or most recent

24

If THERMAL POWER has been increased by ≥ 10% RTP since the ~~last~~ determination of $F_Q^C(Z)$, another evaluation of this factor is required ~~[12]~~ hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

This Frequency condition is not intended to require verification of these parameters after every 10% increase in RTP above the THERMAL POWER at which the last verification was performed. It only requires verification after a THERMAL POWER is achieved for extended operation that is 10% higher than the THERMAL POWER at which $F_Q^C(Z)$ was last measured.

In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^C(Z)$.

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

-----------------------------REVIEWER'S NOTE-----------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
---]

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

The allowance of up to 24 hours after achieving equilibrium conditions at the increased THERMAL POWER level to complete the next $F_Q^C(Z)$ surveillance applies to situations where the $F_Q^C(Z)$ has already been measured at least once at a reduced THERMAL POWER level. The observed margin in the previous surveillance will provide assurance that increasing power up to the next plateau will not exceed the F_Q limit, and that the core is behaving as designed.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. ~~The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called W(Z). Multiplying the measured total peaking factor, $F_Q^C(Z)$, by W(Z) gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.~~

INSERT 3 (Next Page)

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

[T(z)]^{COLR} functions are specified

The ~~W(Z) curve is provided~~ in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for ~~the following~~ axial core regions, measured in percent of core height:

a. Lower core region, from 0 to 15% inclusive, ~~and~~

b. Upper core region, from 85 to 100% inclusive~~.~~,

c. Grid plane regions, ± 2% inclusive, and

d. Core plane regions, within ± 2% of the bank demand position of the control banks.

These regions

~~The top and bottom 15%~~ of the core are excluded from the evaluation because of the low probability that ~~these regions~~ they would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

The excluded regions at the top and bottom of the core are specified in the COLR and are defined to ensure that the minimum margin location is adequately surveilled. A slightly smaller exclusion zone may be specified, if necessary, to include the limiting margin location in the surveilled region of the core.

~~This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.~~

~~If the two most recent $F_Q(Z)$ evaluations show an increase in the expression maximum over z [$F_Q^C(Z)$ / K(Z)], it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)~~

INSERT 3

The measured $F_Q(z)$ can be determined through a synthesis of the measured planar radial peaking factors, $F_{XY}^M(z)$, and the measured core average axial power shape, $P^M(z)$. Thus, $F_Q^C(z)$ is given by the following expression:

$F_Q^C(z) = F_{XY}^M(z)\ P^M(z)\ [1.0815] = F_Q^M(z)\ [1.0815]$

For RAOC operation, the analytical $[T(z)]^{COLR}$ functions, specified in the COLR for each RAOC operating space, are used together with the measured $F_{XY}(z)$ values to estimate $F_Q(z)$ for non-equilibrium operation within the RAOC operating space. When the $F_{XY}(z)$ values are measured at HFP ARO conditions ($A_{XY}(z)$ equals 1.0), $F_Q^W(z)$ is given by the following expression:

$F_Q^W(z) = F_{XY}^M(z)\ [T(z)]^{COLR}\ Rj\ [1.0815]$

Non-equilibrium operation can result in significant changes to the axial power shape. To a lesser extent, non-equilibrium operation can increase the radial peaking factors, $F_{XY}(z)$, through control rod insertion and through reduced Doppler and moderator feedback at part-power conditions.

The $[T(z)]^{COLR}$ functions quantify these effects for the range of power shapes, control rod insertion, and power levels characteristic of the operating space. Multiplying $[T(z)]^{COLR}$ by the measured full power, unrodded $F_{XY}^M(z)$ value, and the factor that accounts for manufacturing and measurement uncertainties gives $F_Q^W(z)$, the maximum total peaking factor postulated for non-equilibrium RAOC operation.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

SURVEILLANCE REQUIREMENTS (continued)

~~-----REVIEWER'S NOTE-----~~
~~WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification," February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~

~~or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.~~

~~Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.~~

~~$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.~~

INSERT 4
(Next Page)

In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^W(z)$.

[The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

-----REVIEWER'S NOTE-----
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
-----]

and that the first required performance of SR 3.2.1.2 after a refueling is performed at a power level high enough to provide a high level of confidence in the accuracy of the Surveillance result.

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after ~~achieving equilibrium conditions after~~ exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. ~~Also, initial startups following a refueling are slow and well controlled due to startup ramp rate limitations and fuel conditioning requirements.~~ Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. ~~Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit.~~ This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged ~~by non-equilibrium operation~~.

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement ~~while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented~~.

T

$F_Q(Z)$ (RAOC-~~W~~(Z) Methodology)
B 3.2.1B

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.
6. WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," February 2019.

T

$F_Q(Z)$ (RAOC-W(Z) Methodology)
B 3.2.1B

Insert new Figure
(Next Page)

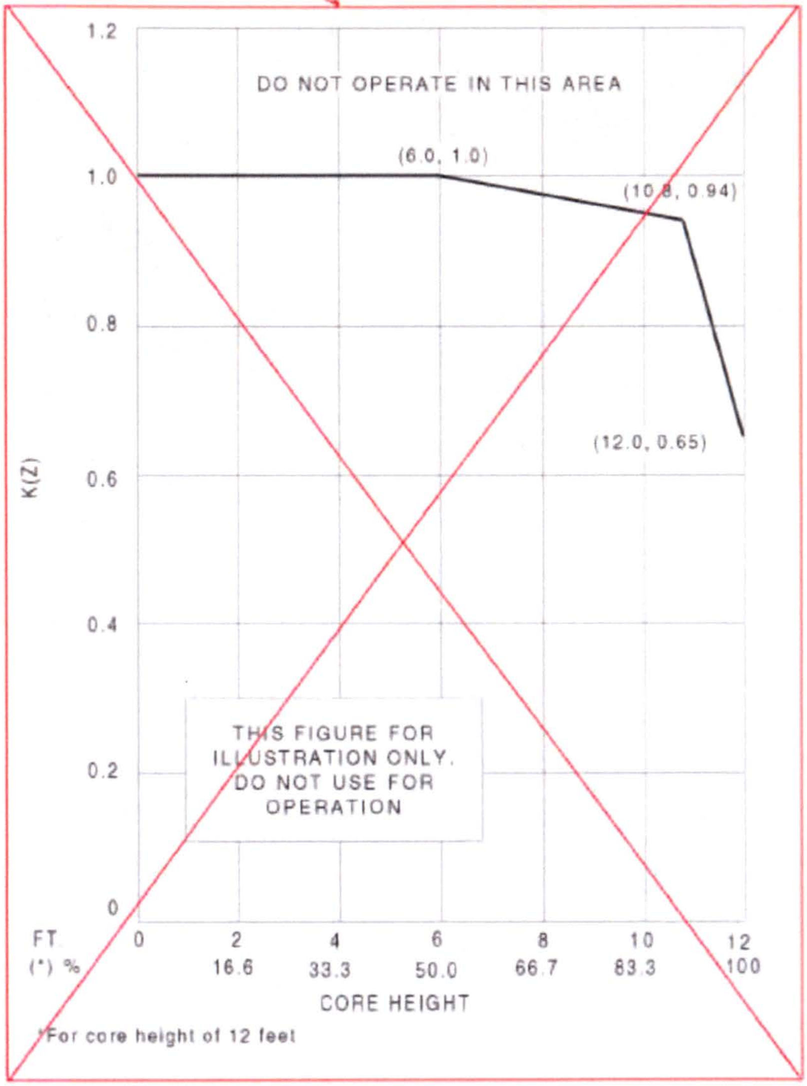
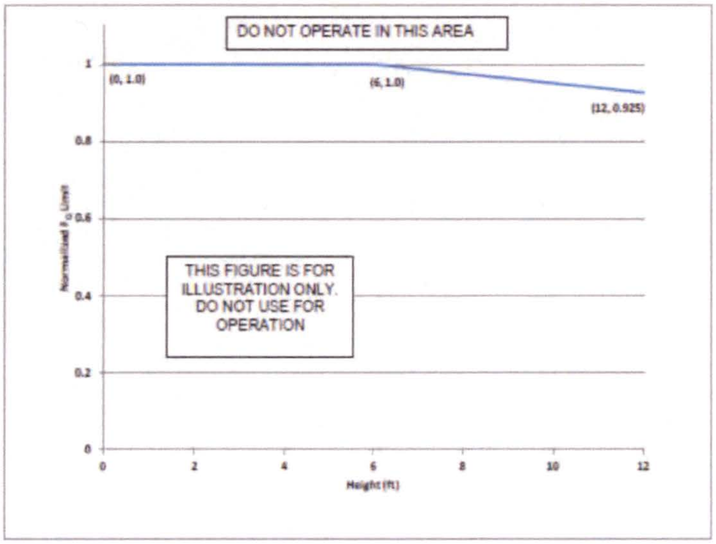


Figure B 3.2.1B-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
(0, 1.0)
(6, 1.0)
(12, 0.925)
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION
Normalized F_Q Limit
Height (ft)
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12

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APPENDIX C
SAMPLE COLR INPUT FOR A RAOC PLANT

In this appendix, sample F_Q Surveillance COLR data for a RAOC plant are presented. Note that only those aspects of the COLR pertinent to F_Q Surveillance are presented in this appendix. Those aspects include COLR data related to Axial Flux Difference, Control Bank Insertion Limits, and the Heat Flux Hot Channel Factor. The approved version of this report must be added to the list of COLR references in Technical Specification 5.6.5, "Core Operating Limits Report (COLR)," since methodology described in this report will be used to determine core operating limits.

C.1 COLR

This COLR for Plant A Cycle XY has been prepared in accordance with the requirements of Technical Specification 5.6.5.

The TSs affected by this report are:

3.1.6 Control Bank Insertion Limits

3.2.1 Heat Flux Hot Channel Factor – $F_Q(z)$

3.2.3 Axial Flux Difference

C.2 OPERATING LIMITS

The cycle-specific parameter limits and associated data for the specifications listed in Section C.1 are presented in the following subsections. These limits and data have been developed using NRC-approved methodologies including those specified in TS 5.6.5.

C.2.1 Control Bank Insertion Limits (Specification 3.1.6)

C.2.1.1:

Control Bank Insertion Limits are provided for three ROSs. The Control Bank Insertion Limits for each ROS shall be used in conjunction with the associated Axial Flux Difference Limits for the ROS. The control rod banks shall be limited in physical insertion as shown in Figure C-1 for ROS1 and ROS2. For ROS3, the control rod banks shall be limited in physical insertion as shown in Figure C-2.

C.2.2 Heat Flux Hot Channel Factor – $F_Q(z)$ (Specification 3.2.1)

C.2.2.1:

$$F_Q^C(z) \leq \frac{F_Q^{RTP}}{P} * K(z) \quad for\ P > 0.5$$

$$F_Q^C(z) \leq \frac{F_Q^{RTP}}{0.5} * K(z) \quad for\ P \leq 0.5$$

where:

$$F_Q^C(z) = F_Q^M(z) * 1.0815$$

$$P = \frac{THERMAL\ POWER}{RATED\ THERMAL\ POWER}$$

C.2.2.2:

$$F_Q^{RTP} = 2.50$$

C.2.2.3:

K(z) is provided in Figure C-3.

C.2.2.4:

$$F_Q^W(z) \leq \frac{F_Q^{RTP}}{P} * K(z) \quad for\ P > 0.5$$

$$F_Q^W(z) \leq \frac{F_Q^{RTP}}{0.5} * K(z) \quad for\ P \leq 0.5$$

where:

$$F_Q^W(z) = [F_{XY}(z)]_{Surv}^M * \frac{[T(z)]^{COLR}}{P} * A_{XY}(z) * R_j * 1.0815$$

and, $[F_{XY}(z)]_{Surv}^M$ is the measured planar radial peaking factor.

C.2.2.5:

$[T(z)]^{COLR}$ values are provided in Tables C-1, C-2, and C-3 for ROS1, ROS2, and ROS3, respectively.

C.2.2.6:

The $A_{XY}(z)$ factors adjust the surveillance to the reference conditions assumed in generating the $[T(z)]^{COLR}$ factors. $A_{XY}(z)$ may be assumed to equal 1.0 or may be determined for specific surveillance conditions using the approved methods listed in TS 5.6.5.

C.2.2.7:

The R_j penalty factors account for the potential decrease in transient F_Q margin between surveillances. The R_j factors for ROS1, ROS2, and ROS3 are provided in Tables C-4, C-5, and C-6, respectively.

C.2.2.8:

Table C-7 provides the required limits on THERMAL POWER and the required AFD reductions for each ROS in the event that additional margin is required.

C.2.3 Axial Flux Difference (Specification 3.2.3)

C.2.3.1:

The Axial Flux Difference limits for ROS1, ROS2, and ROS3 are provided in Figure C-4.

Table C-1 $[T(z)]^{COLR}$ Factors for ROS1

a,c

Note:

1. Axial points 1-5 and 57-61 are excluded. Also, axial points within ±2% of the active core height of a grid location or a bank demand position are excluded.

Table C-2 $[T(z)]^{COLR}$ Factors for ROS2

a,c

Note:

1. Axial points 1-5 and 57-61 are excluded. Also, axial points within ±2% of the active core height of a grid location or a bank demand position are excluded.

Table C-3 $[T(z)]^{COLR}$ Factors for ROS3

a,c

Note:

1. Axial points 1-5 and 57-61 are excluded. Also, axial points within ±2% of the active core height of a grid location or a bank demand position are excluded.

Table C-4 R_j Margin Decrease Factors for ROS1

a,c

Values may be interpolated to the surveillance cycle burnup.

TableC-5 R_j Margin Decrease Factors for ROS2

a,c

Values may be interpolated to the surveillance cycle burnup.

Table C-6 R_j Margin Decrease Factors for ROS3

a,c

Values may be interpolated to the surveillance cycle burnup.

Table C-7 Required THERMAL POWER Limits and AFD Reductions

a,c

Note:

1. AFD reductions should be applied to both the positive and negative sides of the AFD operating space.

a,c

Figure C-1 Control Bank Insertion Limits for RAOC Operating Spaces 1 and 2

*Fully withdrawn shall be the condition where control rods are at a position within the interval ≥ 225 and ≤ 231 steps withdrawn.

NOTE: The Rod Bank Insertion Limits are based on the control bank withdrawal sequence A, B, C, and D and a control bank tip-to-tip distance of 115 steps.

a,c

Figure C-2 Control Bank Insertion Limits for RAOC Operating Space 3

*Fully withdrawn shall be the condition where control rods are at a position within the interval ≥ 225 and ≤ 231 steps withdrawn.

NOTE: The Rod Bank Insertion Limits are based on the control bank withdrawal sequence A, B, C, and D and a control bank tip-to-tip distance of 115 steps.

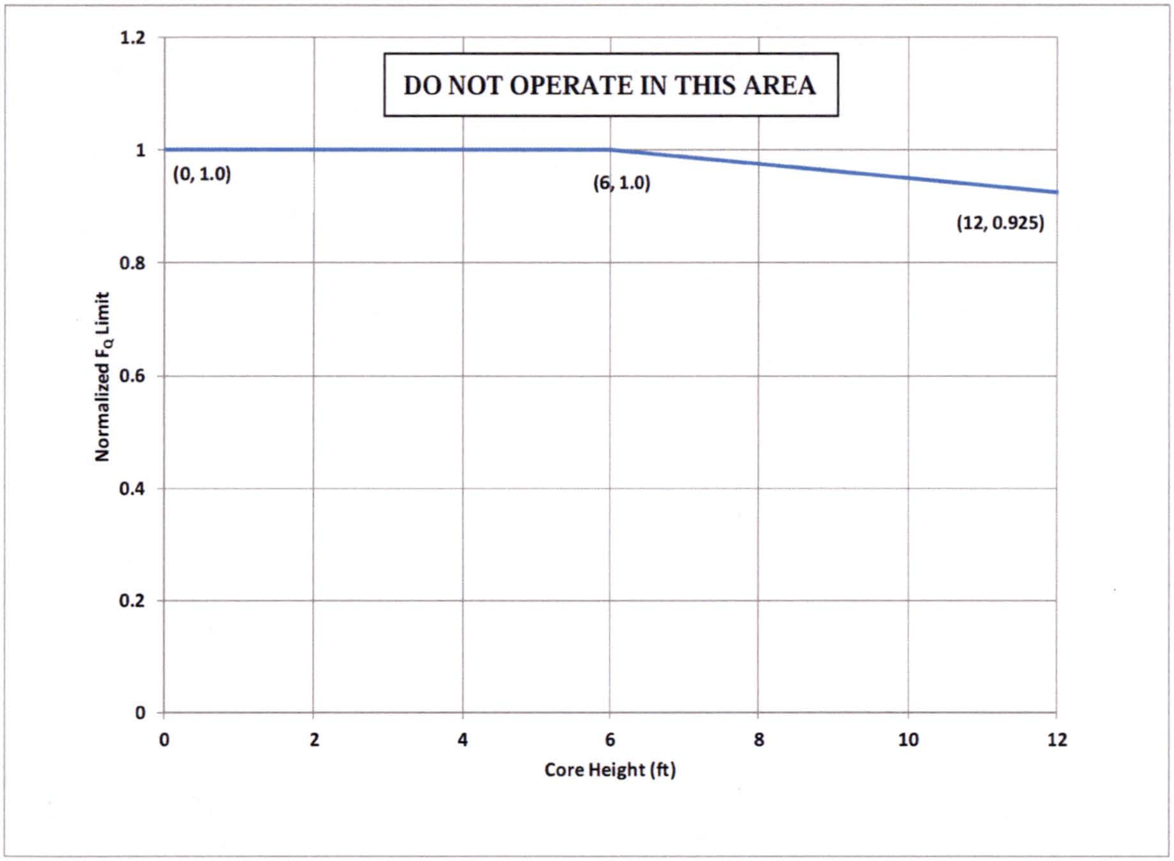

Figure C-3 K(z) – Normalized F_Q Limit as Function of Core Height

a,c

Figure C-4 Axial Flux Difference Limits for ROS1, ROS2, and ROS3

APPENDIX D
IMPROVED CAOC F_Q SURVEILLANCE TS

3.2 POWER DISTRIBUTION LIMITS

3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

LCO 3.2.1C $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling. ------------------------------ $F_Q^C(Z)$ not within limit.	A.1	Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	AND		
	A.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% ~~$F_Q^C(Z)$ exceeds limit.~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.	72 hours after each $F_Q^C(Z)$ determination
	AND		
	A.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% ~~$F_Q^C(Z)$ exceeds limit.~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1.	72 hours after each $F_Q^C(Z)$ determination
	AND		
	A.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

OR
B.2.1 ——————NOTE——————
Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1.
——————————————
Limit THERMAL POWER to less than RATED THERMAL POWER as specified in the COLR.

Implement a CAOC operating space specified in the COLR that restores $F_Q^W(z)$ to within its limits.
AND
B.1.2 Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space.

ACTIONS (continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. ~~——NOTE—— Required Action B.4 shall be completed whenever this Condition is entered. ——————~~	B.1 (.1) ~~Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit.~~	4 hours (72 hours) (4 hours)
	AND	
$F_Q^W(Z)$ not within limits.	B.2 (.2) Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% ~~$F_Q^W(Z)$ exceeds limit.~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1.	72 hours
	AND	
	B.3 (2.3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% ~~$F_Q^W(Z)$ exceeds limit.~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1.	72 hours
	AND	
	B.4 (2.4) Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action B.1 (2.1)
C. Required Action and associated Completion Time not met.	C.1 Be in MODE 2.	6 hours

SURVEILLANCE REQUIREMENTS

~~NOTE~~
~~During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.~~

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP AND Once within [~~12~~ 24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified AND [31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	~~NOTE~~ ~~If measurements indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$:~~ ~~a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or~~ ~~b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has not increased.~~	Once after each refueling within [24] hours after THERMAL POWER exceeds 75% RTP
	Verify $F_Q^W(Z)$ is within limit.	~~Once after each refueling prior to THERMAL POWER exceeding 75% RTP~~ AND Once within [~~12~~ 24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified AND

$F_Q(Z)$ (CAOC-W(Z) Methodology)
3.2.1C

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

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APPENDIX E
IMPROVED CAOC F_Q SURVEILLANCE TS BASES

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO (QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents a equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

In the unlikely event that measurements indicate that the limit for $F_Q^W(z)$ could be exceeded during future non-equilibrium operation, a more restrictive CAOC operating space specified in the Core Operating Limits Report (COLR) may be implemented to restore margin to the $F_Q^W(z)$ limit. A CAOC operating space is a unique combination of an allowable AFD band and Control Bank Insertion Limits. A more restrictive CAOC operating space would employ a narrower AFD band, shallower Control Bank Insertion Limits, or a combination of the two. W(z) functions for each CAOC operating space are specified in the COLR. If none of the CAOC operating spaces provides adequate margin to the $F_Q^W(z)$ limit, then THERMAL POWER must be limited to less than RATED THERMAL POWER.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents.

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$F_Q(Z) \leq$ (CFQ/P) K(Z) for $P > 0.5$

$F_Q(Z) \leq$ (CFQ/0.5) K(Z) for $P \leq 0.5$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized $F_Q(Z)$ as a function of core height provided in the COLR, and

limit

P = THERMAL POWER/RTP

BASES

LCO (continued)

50

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of [2.32], and K(Z) is a function that looks like the one provided in Figure B 3.2.1C-1.

For Constant Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

INSERT 1
(Next Page)

The expression for $F_Q^W(Z)$ is:

$\frac{[W(z)]^{COLR}}{P}\ A_Q(z)\ Rj$

$$F_Q^W(Z) = F_Q^C(Z)\ \cancel{W(Z)}$$

~~where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.~~

Violating the $F_Q(z)$ LCO limits could result in unacceptable consequences if a design basis event were to occur while $F_Q(z)$ exceeds its specified limits.

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. ~~If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required.~~

~~Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.~~

Revised INSERT #1 for Bases B 3.2.1C

$[W(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[W(z)]^{COLR}$ functions are specified for each analyzed CAOC operating space (i.e., each unique combination of AFD band and Control Bank Insertion Limits). The $[W(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each CAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[W(z)]^{COLR}$. The $[W(z)]^{COLR}$ functions also account for the following effects: (1) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (2) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (3) the increase in radial peaking due to non-equilibrium xenon effects. The $[W(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at the Target Axial Offset core conditions. Surveillance specific $[W(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

~~$A_Q(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_Q^M(z)$ to the Target Axial Offset core conditions. For simplicity, $A_Q(z)$ may be assumed to be 1.0 when the surveillance is performed at the target AO. If, however, margin is needed for a Surveillance performed at conditions different from the Target AO core conditions, then the appropriate values for $A_Q(z)$ may be used.~~

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each CAOC operating space.

~~REVIEWER'S NOTE~~

~~WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~

$A_Q(z)$ is a function that adjusts the $F_Q^W(z)$ Surveillance for differences between the reference core condition assumed in generating the $[W(z)]^{COLR}$ function and the actual core condition that exists when the Surveillance is performed. Normally, this reference core condition is defined as the same core condition that is used to establish the target AO (i.e., the target axial flux difference at RTP) in LCO 3.2.3. For simplicity, $A_Q(z)$ can be assumed to be 1.0 when the $F_Q^W(z)$ Surveillance is performed at a core condition consistent with updating the target AO and when Control Bank D is not inserted below the axial elevation where the limiting F_Q margin is predicted to occur (as specified in the COLR). $A_Q(z)$ can also be assumed to be 1.0 if the $F_Q^W(z)$ Surveillance is not performed at conditions consistent with updating the target AO, and a Surveillance specific $[W(z)]^{COLR}$ function associated with performing the Surveillance at the applicable core condition is specified in the COLR. If the conditions specified in the COLR for assuming $A_Q(z)$=1.0 are not met and a Surveillance specific $[W(z)]^{COLR}$ function has not been specified, then the $A_Q(z)$ function is calculated using the NRC approved methodology in Reference 6.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% ~~by which $F_Q^C(Z)$ exceeds its limit,~~ that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1 is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux – High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux – High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux – High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux – High trip setpoints.

BASES

ACTIONS (continued)

that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by ≥ 1% for each 1% ~~by which~~ $\cancel{F_Q^C(Z)}$ ~~exceeds its limit,~~ is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1~~,~~ ensures that core conditions ~~during operation at higher power levels and future operation are consistent with safety analyses assumptions~~.

prior to increasing THERMAL POWER above the limit of Required Action A.1. The Note also states that SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered~~.~~ This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

(if required)

B.1 $\boxed{1}$

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational

INSERT 2
(Next Page)

BASES

ACTIONS (continued)

transient occurs. ~~Reducing the THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, maintains an acceptable absolute power density such that even if a transient occurred, core peaking factors are not exceeded.~~

INSERT 3
(Next Page)

B.2 2

that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% ~~by which $F_Q^W(Z)$ exceeds its limit~~, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in the THERMAL POWER limit in accordance with Required Action B.~~1~~ 2.1.

B.3 2.3

that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% ~~by which $F_Q^W(Z)$ exceeds its limit~~, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in the THERMAL POWER limit in accordance with Required Action B.~~1~~ 2.1.

B.4 2.4

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action B.~~1~~ 2.1 ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

~~Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.~~

INSERT 2

Implementing a more restrictive CAOC operating space, specified in the COLR, within the allowed Completion Time of 4 hours will restrict the AFD such that core peaking factor limits will not be exceeded during non-equilibrium normal operation. Several CAOC operating spaces, representing successively smaller AFD bands and, optionally, shallower Control Bank Insertion Limits, may be specified in the COLR. The corresponding $[W(z)]^{COLR}$ functions for these operating spaces can be used to determine which CAOC operating space would result in acceptable non-equilibrium operation within the $F_Q^W(Z)$ limit.

INSERT 3

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new CAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new CAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new CAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(Z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(Z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

INSERT 3 (continued)

The Completion Time of 4 hours provides an acceptable time to reduce power in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(z)$ and would require power reductions within 4 hours of the $F_Q^W(z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

BASES

ACTIONS (continued)

C.1

2.4

If Required Actions A.1 through A.4 or B.1 through B.~~4~~ are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

~~SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.~~

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

some determination of $F_Q^C(z)$ is made prior to achieving a significant power level where the peak linear heat rate could approach the limits assumed in the safety analyses.

following a refueling

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that ~~the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.~~

initial or most recent

24

If THERMAL POWER has been increased by ≥ 10% RTP since the ~~last~~ determination of $F_Q^C(Z)$, another evaluation of this factor is required [~~12~~] hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

This Frequency condition is not intended to require verification of these parameters after every 10% increase in RTP above the THERMAL POWER at which the last verification was performed. It only requires verification after a power level is achieved for extended operation that is 10% higher than the THERMAL POWER at which $F_Q^C(z)$ was last measured.

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^C(z)$.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

----------------------------REVIEWER'S NOTE----------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

The allowance of up to 24 hours after achieving equilibrium conditions at the increased THERMAL POWER level to complete the next $F_Q^C(Z)$ surveillance applies to situations where the $F_Q^C(Z)$ has already been measured at least once at a reduced THERMAL POWER level. The observed margin in the previous surveillance will provide assurance that increasing power up to the next plateau will not exceed the F_Q limit, and that the core is behaving as designed.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called ~~W(Z)~~. Multiplying the measured total peaking factor, $F_Q^C(Z)$, by ~~W(Z)~~ gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.

$[W(z)]^{COLR}$

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

$[W(z)]^{COLR}$ factors are

The ~~W(Z) curve is~~ provided in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for ~~the following axial core regions, measured in percent of core height:~~

axial core regions near the top and bottom of the core. The excluded regions, usually the top and bottom [15]%, are specified in the COLR and are defined to ensure that the minimum margin location is adequately surveilled. A slightly smaller exclusion zone may be specified, if necessary, to include the limiting margin location in the surveilled region of the core.

~~a. Lower core region, from 0 to 15% inclusive and~~

~~b. Upper core region, from 85 to 100% inclusive.~~

they

These regions

~~The top and bottom 15%~~ of the core are excluded from the evaluation because of the low probability that ~~these regions~~ would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.

If the two most recent $F_Q(Z)$ evaluations show an increase in the expression

maximum over z $[F_Q^C(Z) / K(Z)]$,

it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)

BASES

SURVEILLANCE REQUIREMENTS (continued)

~~-----REVIEWER'S NOTE-----~~
~~WCAP-10216-P-A, Rev. 1A, Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification, February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~
~~----------~~

INSERT 4
(Next Page)

~~or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.~~

~~Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.~~

~~$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.~~

In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^W(z)$.

~~[~~The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

-----REVIEWER'S NOTE-----
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
----------]

and that the first required performance of SR 3.2.1.2 after a refueling is performed at a power level high enough to provide a high level of confidence in the accuracy of the Surveillance result.

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after ~~achieving equilibrium conditions after~~ exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. ~~Also, initial startups following a refueling are slow and well-controlled due to startup ramp rate limitations and fuel conditioning requirements.~~ Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. ~~Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit.~~ This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged ~~by non-equilibrium operation.~~

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement ~~while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented~~.

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.
6. WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," February 2019.

$F_Q(Z)$ (CAOC-W(Z) Methodology)
B 3.2.1C

Insert new Figure
(Next Page)

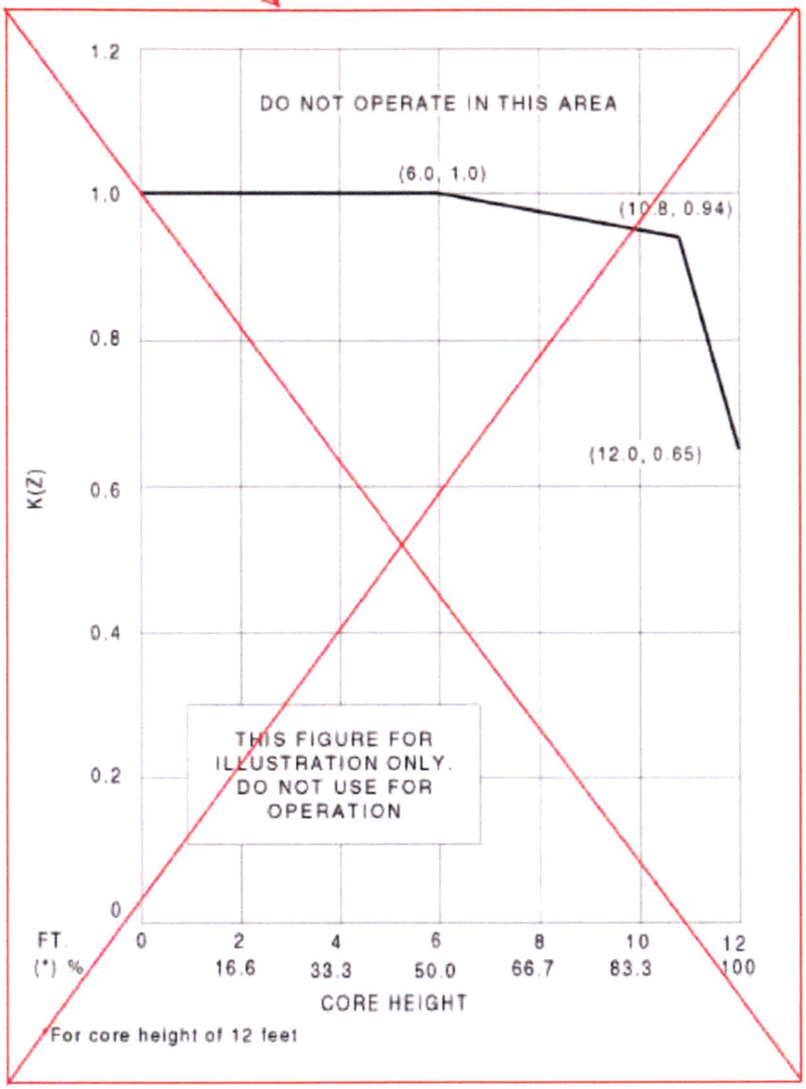
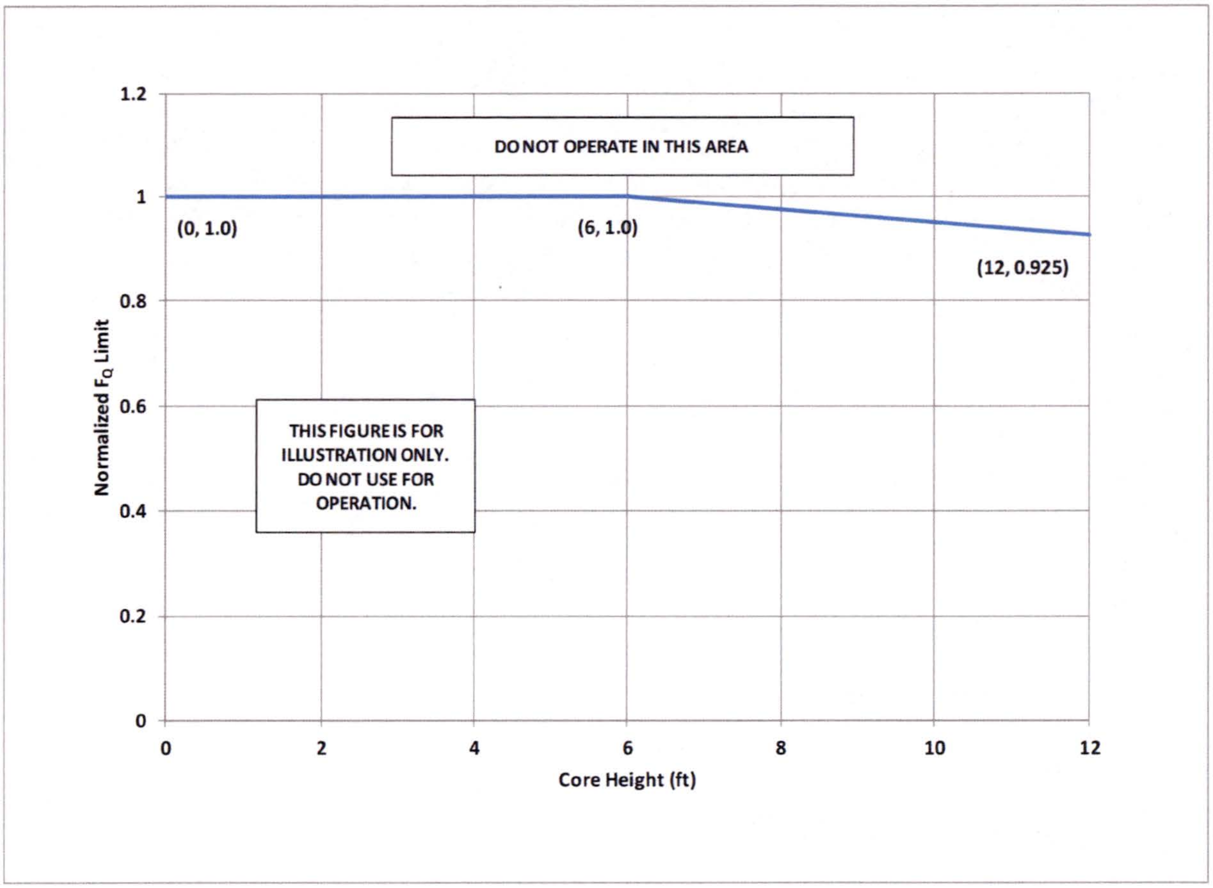


Figure B 3.2.1C-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
(0, 1.0)
(6, 1.0)
(12, 0.925)
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION.
Normalized F_Q Limit
Core Height (ft)
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12

APPENDIX F
SAMPLE COLR INPUT FOR A CAOC PLANT

In this appendix, sample F_Q Surveillance COLR data for a CAOC plant are presented. Note that only those aspects of the COLR pertinent to F_Q Surveillance are presented in this appendix. Those aspects include COLR data related to Axial Flux Difference, Control Bank Insertion Limits, and the Heat Flux Hot Channel Factor. The approved version of this report must be added to the list of COLR references in TS 5.6.5, "Core Operating Limits Report (COLR)", since methodology described in this report will be used to determine core operating limits.

F.1 COLR

This COLR for Plant A Cycle XY has been prepared in accordance with the requirements of TS 5.6.5.

The TSs affected by this report are:

3.1.6 Control Bank Insertion Limits

3.2.1 Heat Flux Hot Channel Factor - $F_Q(z)$

3.2.3 Axial Flux Difference

F.2 OPERATING LIMITS

The cycle-specific parameter limits and associated data for the specifications listed in Section F.1 are presented in the following subsections. These limits and data have been developed using NRC-approved methodologies including those specified in TS 5.6.5.

F.2.1 Control Bank Insertion Limits (Specification 3.1.6)

F.2.1.1:

Control Bank Insertion Limits are provided for three COSs. The Control Bank Insertion Limits for each COS shall be used in conjunction with the associated Axial Flux Difference Limits for the COS. The control rod banks shall be limited in physical insertion as shown in Figure F-1 for COS1, COS2, and COS3.

F.2.2 Heat Flux Hot Channel Factor – $F_Q(z)$ (Specification 3.2.1)

F.2.2.1:

$$F_Q^C(z) \leq \frac{F_Q^{RTP}}{P} * K(z) \quad for\ P > 0.5$$

$$F_Q^C(z) \leq \frac{F_Q^{RTP}}{0.5} * K(z) \quad for\ P \leq 0.5$$

where:

$$F_Q^C(z) = F_Q^M(z) * 1.0815$$

$$P = \frac{THERMAL\ POWER}{RATED\ THERMAL\ POWER}$$

F.2.2.2:

$$F_Q^{RTP} = 2.50$$

F.2.2.3:

K(z) is provided in Figure F-2.

F.2.2.4:

$$F_Q^W(z) \leq \frac{F_Q^{RTP}}{P} * K(z) \quad for\ P > 0.5$$

$$F_Q^W(z) \leq \frac{F_Q^{RTP}}{0.5} * K(z) \quad for\ P \leq 0.5$$

where:

$$F_Q^W(z) = F_Q^C(z) * \frac{[W(z)]^{COLR}}{P} * A_Q(z) * R_j$$

F.2.2.5:

$[W(z)]^{COLR}$ values are provided in Tables F-1, F-2, and F-3 for COS1, COS2, and COS3, respectively.

F.2.2.6:

The $A_Q(z)$ factor adjusts the surveillance to the Target AO conditions. $A_Q(z)$ can be assumed to be equal to 1.0 if the conditions discussed below are met, or may be determined for specific surveillance conditions using the approved methods listed in WCAP-17661. Specifically, $A_Q(z)$ can be assumed to be equal to 1.0 if the surveillance is performed at core conditions consistent with updating the measured Target AO and Control Bank D is not inserted below 200 steps withdrawn[1]. Alternatively, $A_Q(z)$ can be assumed to be equal 1.0 if a surveillance specific W(z) function is being used that is consistent with the core conditions of the surveillance.

1. Reviewers Note: The Control Bank D insertion requirement will be determined on a cycle specific basis, based on bounding the predicted limiting axial elevation for the $F_Q^Z(w)$ margin. This single value can also be replaced with a table of Control Bank D insertion as a function of cycle burnup.

F.2.2.7:

The R_j penalty factors account for the potential decrease in transient F_Q margin between surveillances. The R_j factors for COS1, COS2, and COS3 are provided in Tables F-4, F-5, and F-6, respectively.

F.2.2.8:

Table F-7 provides the required limits on thermal power for each COS in the event that additional margin is required.

F.2.3 Axial Flux Difference (Specification 3.2.3)

F.2.3.1:

The AFD target bands for COS1, COS2, and COS3 are provided in Table F-8.

F.2.3.2:

The AFD Acceptable Operation Limits are provided in Figure F-3.

Table F-1 $[W(z)]^{COLR}$ Factors for COS1

a,c

Note:
1.Axial points 1-5 and 57-61 are in the exclusion zone and are not included in the table.

Table F-2 $[W(z)]^{COLR}$ Factors for COS2

a,c

Note:
1.Axial points 1-5 and 57-61 are in the exclusion zone and are not included in the table.

Table F-3 $[W(z)]^{COLR}$ Factors for COS3

a,c

Note:
1.Axial points 1-5 and 57-61 are in the exclusion zone and are not included in the table.

Table F-4 R_j Margin Decrease Factors for COS1

a,c

Values may be interpolated to the surveillance cycle burnup.

Table F-5 R_j Margin Decrease Factors for COS2

a.c

Values may be interpolated to the surveillance cycle burnup.

Table F-6 R_j Margin Decrease Factors for COS3

a,c

Values may be interpolated to the surveillance cycle burnup.

Table F-7 Required THERMAL POWER Limits

a.c

Table F-8 CAOC Axial Flux Difference Operating Bands

a,c

a,c

Figure F-1 Control Bank Insertion Limits for CAOC Operating Spaces 1, 2, and 3

*Fully withdrawn shall be the condition where control rods are at a position within the interval ≥ 225 and ≤ 231 steps withdrawn.

NOTE: The Rod Bank Insertion Limits are based on the control bank withdrawal sequence A, B, C, and D and a control bank tip-to-tip distance of 115 steps.

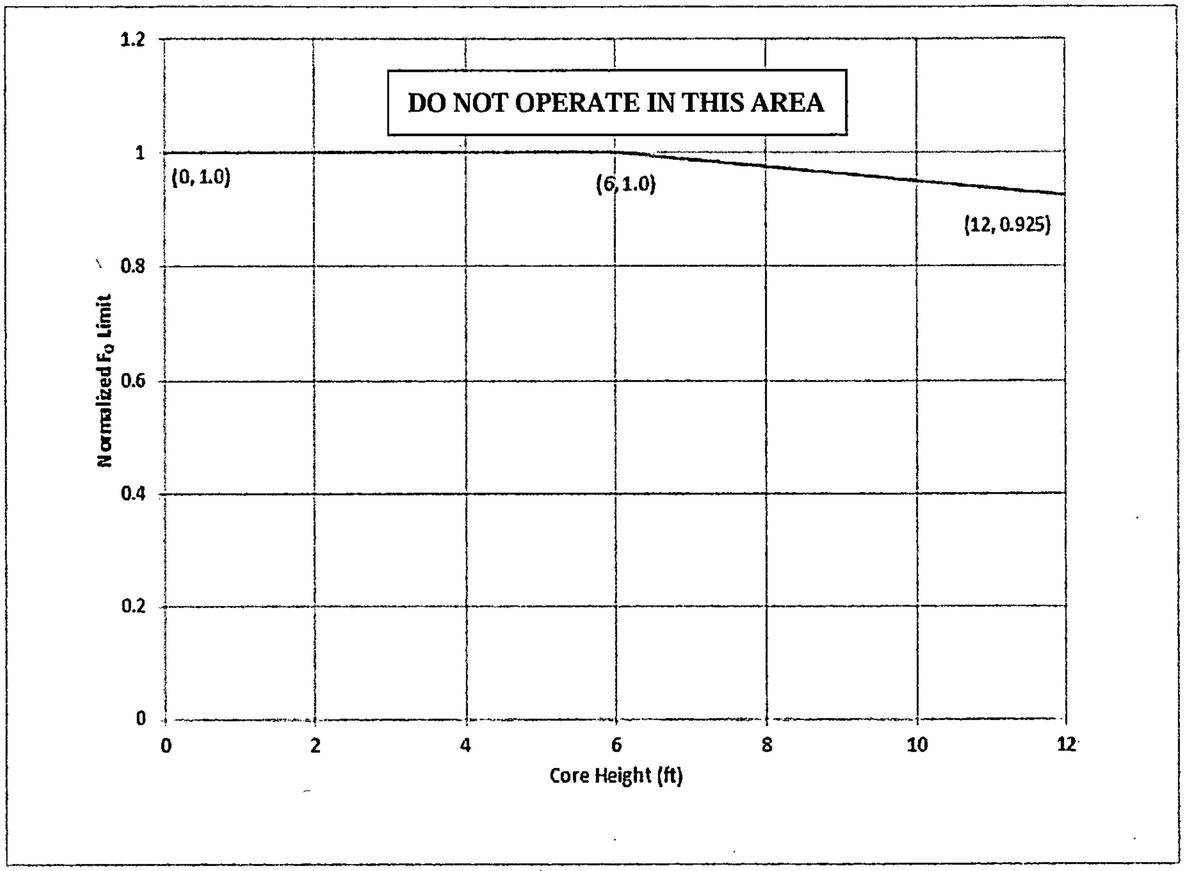


Figure F-2 K(z) – Normalized F_Q Limit as Function of Core Height

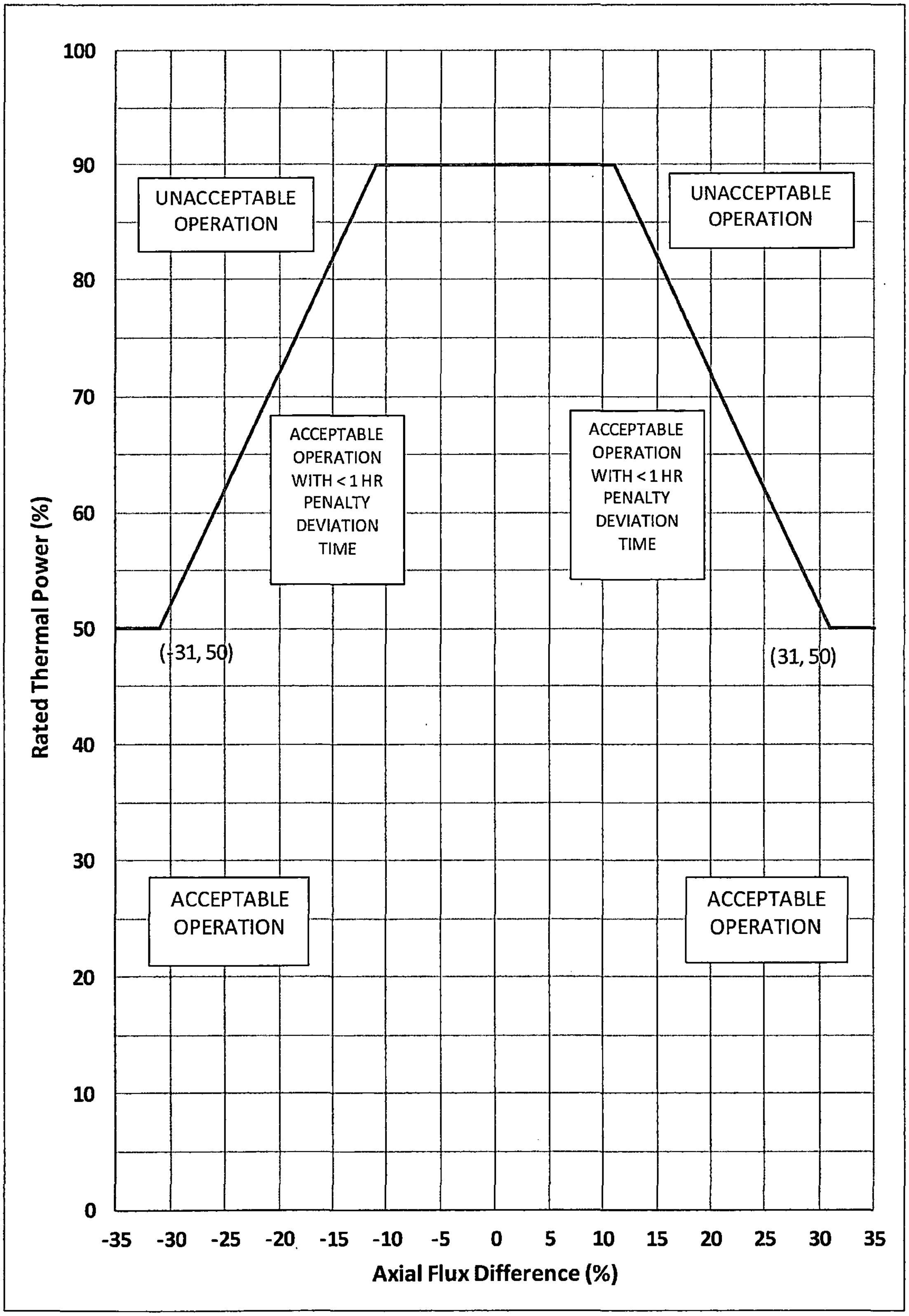


Figure F-3 Axial Flux Difference Acceptable Operation Limits

APPENDIX G

PWROG CORRESPONDENCE AND RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION

Includes the following correspondence:

1. NRC Letter for Request for Additional Information RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated December 24, 2014 (TAC NO. MF3348)

2. Letter OG-16-273, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated September 13, 2016
   - Enclosure 2: Attachment 2, PWROG Request For Additional Information Response and revised markup of Technical Specification (TS) 3.2.1B and 3.2.1C (Non-Proprietary)
   - Enclosure 2: Attachments 3-6, PWROG revised markup of Technical Specification (TS) 3.2.1B and 3.2.1C (Non-Proprietary)

3. Email from the NRC (Benney) to the PWROG (Holderbaum), Request for Additional Information, RAI 15, RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 27, 2017 (Non-Proprietary)

4. OG-18-35, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795", dated February 15, 2018
   - Enclosure 2: Attachment 2, "RAI-15 Response forWCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Non-Proprietary)
   - Enclosure 3: Attachment 3, "Revision to "Insert 1" in the Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273" (Non- Proprietary)
   - Enclosure 4: Attachment 4, "Revision to Section F.2.2.6 on Page F-2 of WCAP-17661, Revision 1 (Sample COLR Input for a CAOC Plant)" (Non- Proprietary)

5. Email from the NRC (Benney) to the PWROG (Holderbaum), Draft Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Pressurized Water Reactor Owners' Group Licensing Topical Report WCAP-17661, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated, April 30, 2018 (Non-Proprietary)

APPENDIX G

PWROG CORRESPONDENCE AND RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION

Includes the following correspondence (continued):

6. OG-18-188, "Transmittal of the Response to the Revised Draft Safety Evaluation (DSE) for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795)", dated August 2, 2018

- Enclosure 1: Attachment 1, Comments on the DSE for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795) (Non-Proprietary)
- Enclosure 2: Attachment 2, "Revision to the Technical Specification (TS) Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 (Non-Proprietary)
- Enclosure 3: Attachment 3, "Revision to the TS Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 and OG-18-35" (Non-Proprietary)
- Enclosure 4: Attachment 4, "WCAP-17661-P/ WCAP-17661-NP, Revision 1 Markup Pages" (PA-LSC-0795) (Non-Proprietary)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 24, 2014

Mr. W. Anthony Nowinowski, Program Manager
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: PRESSURIZED WATER REACTOR OWNERS GROUP TOPICAL REPORT WCAP-17661-P/NP, REVISION 1, "IMPROVED RAOC AND CAOC F_Q SURVEILLANCE TECHNICAL SPECIFICATION" (TAC NO. MF3348)

Dear Mr. Nowinowski:

By letter dated January 2, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML14009A092), the Pressurized Water Reactor Owners Group submitted Topical Report, WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," for U.S. Nuclear Regulatory Commission (NRC) staff review. Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. Mr. Chad Holderbaum, of your staff, and I agreed that the NRC staff will receive your response to the enclosed request for additional information (RAI) questions by January 30, 2015.

If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-4053.

Sincerely,

Jonathan G. Rowley, Project Manager
Licensing Processes Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure:
Request for Additional Information

REQUEST FOR ADDITIONAL INFORMATION QUESTIONS

PRESSURIZED WATER REACTOR OWNERS GROUP

TOPICAL REPORT WCAP-17661-P/NP, REVISION 1, "IMPROVED RAOC AND CAOC F_Q SURVEILLANCE TECHNICAL SPECIFICATION"

RAI No. 1: Required Actions when both $F_Q^C(z)$ and $F_Q^W(z)$ exceed limits

Background

Under the proposed change for both relaxed axial offset control (RAOC) heat flux hot channel factor ($F_Q(Z)$) Surveillance (TS 3.2.1B) and constant axial offset control (CAOC) $F_Q(Z)$ Surveillance (TS 3.2.1C), Required Actions are now different for Condition A and B. When $F_Q^C(Z)$ is not within limits, reduction of THERMAL POWER is required along with reduction of setpoints and performance of Surveillance Requirement (SR) 3.2.1.1 and SR 3.2.1.2. Whereas, when $F_Q^W(Z)$ is not within limits, two alternative actions may be applicable. Required Action B.1 requires implementation of a different operating space and if an appropriate operating space cannot be implemented, reduction of THERMAL POWER and setpoints and performance of SR 3.2.1.1 and SR 3.2.1.1 are required. The proposed change in Required Action when $F_Q^W(Z)$ exceeds limits is intended to avoid THERMAL POWER reduction through implementation of a different operating space (Required Action B.1).

Issue and Request

Under the proposed change, when $F_Q^C(Z)$ is within limits and $F_Q^W(z)$ is not within limits, a different operating space may be implemented and a THERMAL POWER reduction will not be required. However, when both $F_Q^C(Z)$ and $F_Q^W(Z)$ are not within limits, Required Action for $F_Q^C(Z)$ will require reduction of THERMAL POWER. The corresponding evaluation and action for $F_Q^W(Z)$ require clarification. For example, Condition A ($F_Q^C(Z)$ not within limit) requires reduction of THERMAL POWER greater than or equal to (≥) 1 percent (%) for each 1% $F_Q^C(Z)$ exceeds the limit, but Condition B ($F_Q^W(Z)$ not within limit) may require reduction of THERMAL POWER which may be evaluated for 5% decrements in the core operating limit report (COLR). Also, implementation of Required Action B.1 is unclear since the action does not involve reduction of THERMAL POWER.

a. Provide a complete explanation and justification for the THERMAL POWER actions that will be taken when *both* $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits including how the COLR evaluations will be used. Discuss the compatibility of actions for $F_Q^C(Z)$ and $F_Q^W(Z)$ and the supporting evaluations in the COLR.

b. Based on the discussion and the need for clarity of the Required Actions when both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed limits, discuss the need for a NOTE in the Required Action column that may be useful for the operators in abiding by these specifications.

Enclosure

RAI No. 2: Need to perform SR 3.2.1.2 when $F_Q^C(Z)$ not within limit following refueling prior to THERMAL POWER exceeding 75% rated thermal power (RTP)

Background

Under the proposed change for SR 3.2.1.2, "Verify $F_Q^W(Z)$ is within limit," the first frequency is revised whereby instead of conducting the surveillance "Once after each refueling prior to THERMAL POWER exceeding 75% RTP [rated thermal power]" the requirement will be "Once after each refueling within [24] hours after achieving equilibrium conditions *after* [emphasis added] THERMAL POWER exceeds 75% RTP." This change makes the SR for $F_Q^C(Z)$ and $F_Q^W(Z)$ different, i.e., following refueling, $F_Q^C(Z)$ is checked prior to exceeding 75% RTP whereas $F_Q^W(Z)$ is checked after exceeding 75% RTP. The primary justification for not conducting the surveillance for $F_Q^W(Z)$ below 75% RTP is that, during power ascension, $F_Q^W(Z)$ calculations are not reliable at such power levels.

Issue and Request

The justification for not conducting the $F_Q^W(Z)$ surveillance following refueling prior to exceeding the 75% RTP seems valid and appropriate. However, because of the change, an apparent contradiction is noted. Condition A, $F_Q^C(Z)$ not within limit, may occur prior to THERMAL POWER exceeding 75% RTP. Required Action A.4, "Perform SR 3.2.1.1 and SR 3.2.1.2," will involve unnecessary performance of SR 3.2.1.2.

Provide either an explanation or correction for this situation.

RAI No. 3: Changes to SR 3.2.1.2

Background

Section 3.2.5 states (Page 3-16):

> The first Frequency for SR 3.2.1.2 [currently requiring performance of $F_Q^W(Z)$ surveillance "Once after each refueling prior to THERMAL POWER exceeding 75% RTP"] will be changed to state that $F_Q^W(Z)$ must be verified to be within its limit following each refueling within 24 hours after achieving equilibrium conditions after thermal power exceeds 75% RTP... This change is justified since initial startups following a refueling are slow and tightly controlled due to startup ramp rate limitations and fuel conditioning requirements. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit. Also, core power distribution measurements taken at low powers (< 50% RTP) to confirm that the core is loaded properly will provide ample indication that the core is operating consistent with expectations. The new Frequency will ensure that verification of $F_Q^W(Z)$ is performed within a reasonable time period and prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

Page B-1 provides a BASES[1] definition of equilibrium conditions: "being at a stable reactor power (i.e., within plus or minus (±) 1% RTP) and at stable axial flux conditions (i.e., with an axial flux difference variability of ± 1% over the previous 24 hours."

Issue and Request

It is not clear that the "new Frequency will ensure that verification of $F_Q^W(Z)$ is performed... *prior to extended non-equilibrium* [emphasis added] operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged," because the new surveillance requirement would permit operation above 75% RTP, *prior to achieving equilibrium conditions*, without performing an initial surveillance. Therefore, as acknowledged in the proposed BASES, "In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^W(Z)$."

The current version of the SR establishes an unambiguous requirement to verify $F_Q^W(Z)$ prior to exceeding 75% RTP and generally every 31 EFPD thereafter (or in accordance with the Surveillance Frequency Control Program). The improved TS should also establish an unambiguous requirement to perform an initial surveillance, followed by periodic surveillances on an appropriately justified frequency.

a. Provide analyses of past data of initial surveillance of $F_Q^W(Z)$ prior to exceeding 75% RTP following a refueling to demonstrate that surveillance at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment.

b. Justify the 24 hours for completing the surveillance after achieving the equilibrium condition, particularly since 24 hours has elapsed to establish an equilibrium condition.

RAI No. 4: Treatment of uncertainties in $F_Q^C(Z)$ and $F_Q^W(Z)$ determination and in defining the requirements

Background

One of the multiplicative factors that determines $F_Q^C(Z)$ and $F_Q^W(Z)$ is the uncertainty U_F which accounts for measurement and manufacturing uncertainties. It is typically 1.0815 (Page 3-2), which is the result of multiplying a measurement uncertainty of 1.05 by a manufacturing uncertainty of 1.03. The sample COLR input given in Appendices C and F do not refer to U_F but do use 1.0815 as one the factors determining the above $F_Q(Z)$ quantities. It is not stated if these uncertainties represent 1-sigma or a 95/95 uncertainty. The use of a measurement uncertainty is obvious but the use of an uncertainty to account for manufacturing tolerances is less clear.

[1] NRC staff reviews the proposed BASES for information only and issues requests to obtain clarification and improve the interpretability of the proposed TS; however, plant-specific BASES are administratively controlled and the NRC staff does not intend to extend approval to the BASES provided in WCAP-17661-P Appendices, or to any plant proposing to implement WCAP-17661-P.

Another factor defining $F_Q^W(Z)$ is the T(z) function. According to the statement made with respect to Equations 2-23 and 2-24, the T(z) functions are derived with "appropriate uncertainties."

Issue and Request

A better discussion of the treatment of uncertainties in the methodology, in the calculated parameters, and how they are addressed in defining the requirements is appropriate.

a. Explain how uncertainties are taken into account in defining the $F_Q^C(Z)$ and $F_Q^W(Z)$ that are monitored.

b. It is understood that part of the uncertainty is the result of the surveillance measurement of planar radial peaking factor ($F_{XY}(Z)$) and part the result of the analysis to obtain T(z). The T(z) uncertainty is expected to be incorporated into the tabulation of these functions but the measurement uncertainty would be explicitly given in the COLR if it is a function of the particular reactor and fuel cycle or explicitly given and explained in the topical report if it is a generic number. Explain which of these options is being recommended and why.

RAI No. 5: New Required Action B.1 requiring implementation of a RAOC/CAOC operating space

Background

Under the proposed change, Required Action B.1 states:

> Implement a RAOC/CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within its limits.

As stated on Page 3-14 of WCAP-17661-P,

> Pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be included in the COLR and characterized by transient (T(z) functions) which, in conjunction with measured radial peaking factors, may be used to quantify margin and ensure compliance with the LCO for future non-equilibrium operation. Analogous to the CAOC operating space concept..., a RAOC operating space is a unique combination of AFD [axial flux difference] operating space envelope and control rod bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient F_Q margin, maximum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the required reductions will be included in the COLR.

In addition, as part of the change for both RAOC and CAOC plants, the NOTE in Condition B stating that Required Action B.4 shall be completed whenever this Condition is entered is deleted. A NOTE in the Required Action column under Required Action B.2.1 is entered stating that Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed.

(Both B.4 in the previous version and B.2.4 in the revised version are the same Required Action, "Perform SR 3.2.1.1 and SR 3.2.1.2)." In effect, SRs will no longer be applicable when Required Action B.1 is implemented.

Issue and Request

Based on the analysis presented, the use of a different operating space is generally an appropriate approach to gain margin improvement. However, if changing the rod insertion limits (RILs) is part of the new operating space AND that requires movement of control rods to comply, then this approach puts the reactor into a new operating condition.

In addition, in order to understand if the new operating space will provide the needed margin, it is necessary for the reactor engineer to evaluate $F_Q^W(Z)$ using the T(z) for different operating spaces. This must be done within four hours, the TS completion time.

If movement of control rods was required, a reevaluation of $F_Q^C(Z)$ and $F_Q^W(Z)$ will be required to assure that TS requirements are being met. In other words, the NOTE may apply to B.1 for such situations.

Explain the use of Required Action B.1 incorporating the response to the following:

a. Explain what would be done if Required Action B.1 is carried out and requires movement of control rods.

b. Explain if in addition to the T(z) tables there will be tables to show the margin improvement as a function of axial position or some other scheme in the COLR to make it easier for the reactor engineer to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary.

c. Explain the deletion of the NOTE to perform SR 3.2.1.1 and SR 3.2.1.2 under required Action B.1

d. Discuss clearly the specific actions (e.g., how are the rod insertion limits imposed) that will be undertaken by the operator in implementing the new operating space and consequently what would constitute a violation of this required action.

RAI No. 6: Effect of Crud Induced Power Shift

Background

Currently, any downward trend in margin (as defined by the minimum margin over all axial locations) is accounted for by applying a penalty factor and requiring additional surveillance. This is specified in a note modifying SR 3.2.1.2, which is proposed to be eliminated. This NOTE monitored increases in $F_Q^W(Z)$ from the previous surveillance and required additional surveillances if measurements indicated that the maximum over z of $F_Q^C(Z)/K(Z)$ has increased since the previous evaluation of $F_Q^C(Z)$.

In lieu of this approach, it is proposed that a penalty factor be applied that takes account of the *expected* change in margin during the next effective full power minutes as a result of normal changes in burnup. This approach eliminates any action due to the concern over crud induced power shift (CIPS). Reasons are given for this (Page 4-18).

One of the arguments presented is that past trends of $F_Q^C(Z)/K(Z)$ may or may not be indicative of future trends. It is justified to remove monitoring of $F_Q^C(Z)/K(Z)$ for indication of future margin trends if it does not provide the required indication.

Request

It is stated (Page 4-18):

> ...given that CIPS develops slowly and characteristically, it is proposed that its effects on peaking factor be evaluated in a timely fashion following its observed onset.

Although the TS is designed to monitor power peaking, it appears that the licensee will now have full discretion as to how monthly trends due to any anomalous behavior are taken into account.

a. Explain how this would actually take place.

b. Provide data from past experience and additional discussion supporting the statement "past measurement trends of $F_Q^C(Z)/K(Z)$ may or may not be indicative of future margin trends."

RAI No. 7: Change of Required Action B.2.1 and limitation of THERMAL POWER to ≤ 50% RTP

Background

The improved TS define a new Required Action B.2. When $F_Q^W(Z)$ exceeds its limits, Required Actions B.2.1, B.2.2, B.2.3, and B.2.4 can be implemented instead of Required Action B.1. Required Action B.2.1 limits thermal power to less than RTP by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Action B.2.1 must be entered and THERMAL POWER must be reduced to less than the thermal power specified in the COLR. Also, AFD limits must be reduced by the amount specified in the COLR.

It is also noted that as a practical matter, the number of discrete reduced power level evaluations included in the COLR will be limited to three or less (an individual utility may opt for additional evaluation levels). Also stated in WCAP-17661-P, if the required margin improvement exceeds the level of any pre-analyzed thermal power limits, the COLR will specify that the thermal power is limited to <50 percent RTP. WCAP-17661-P also states that other TS, such as the Nuclear Enthalpy Rise Hot Channel Factor TS, would also require a power level reduction in the presence of such a large anomaly.

Issue and Request

For situations where necessary margin improvement exceeds the level of any pre-analyzed thermal power limits, the requirement to reduce the thermal power to less than 50 percent RTP is not noted in the Technical Specifications (TS) or in the Bases. Since this type of situation means that a very large and unusual core anomaly is present, clear guidance and justification for the actions should be presented.

a. Explain how the required actions in the COLR for Required Action B.2.1 will be sufficient if $F_Q^W(Z)$ is not within limits. For example, will some limit of power to 50% RTP always be imposed and if so, at what point (vis-a-vis margin needed) would that be required.

b. Since the reduction of thermal power to < 50% RTP is a defined parameter applicable to all Westinghouse plants, explain why this requirement should not be included in the TS and/or Bases.

RAI No. 8: Implementation of 24-Hour Frequency in TS SR 3.2.1.1 and 3.2.1.2

Background

Section 3.2.4 states (Pages. 3-14 and 3-15):

> In the improved F_Q TS, the second Frequency will be revised to require verification of $F_Q^C(Z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10% RTP , the THERMAL POWER at which $F_Q^C(Z)$ was last verified. This Frequency of 24 hours is contained in some plant Technical Specifications. (for a few plants, no Frequency is specified) and is a reasonable time period in which to perform this verification given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The information is repeated in Sections 5.4 and 8.4 and a similar change is proposed for SR 3.2.1.2, related to surveillance of $F_Q^W(Z)$.

The purpose of bracketed information in Standard Technical Specifications is to denote site-specific information, which must be in conformance with the final safety analysis report as updated. Refer to Chapter 16.0, "Technical Specifications," of NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*, for further details.

Issue and Request

Since Pressurized Water Reactor Owners Group (PWROG) proposes to use WCAP-17661 as a basis to reduce the frequency requirement for these surveillance test intervals, a more thorough technical justification for the change should be provided. The justification should either follow a clearly risk-informed or deterministic approach, rather than provide a qualitative assessment of the likelihood of limiting initial conditions or initiating events.

If risk-informed, the appropriate regulatory guidance should be followed. This would include NRC Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," and RG 1.177, "An Approach for Plant-Specific, Risk-Informed Decision Making: Technical Specifications."

If deterministic, the justification could include consideration of the consequences of a postulated event occurring in a condition in which the extended surveillance interval prevented assurance that operation was within specified limiting conditions, and of additional mitigating features that would ensure that continued operation in such a condition remains otherwise acceptable. Finally, consider whether plant-specific submittal items should be identified, which would justify any facility licensing basis changes required to implement the proposed TS change.

RAI No. 9: Equilibrium vs Stable Conditions

Background

The SR for $F_Q^C(Z)$ requires a measurement "Once after each refueling prior to THERMAL POWER exceeding 75% RTP." According to the BASES (Page B-1), equilibrium conditions are not required for this measurement but rather stable conditions are required. Both equilibrium and stable conditions require that the power be within ± 1% but for equilibrium, this condition must exist for 24 hours. Equilibrium conditions also require that the AFD be within ± 1% for that 24-hour period but stable conditions just require that the AFD be within ± 0.5% during the period of interest (when the measurement is being done).

Issue and Request

All surveillance requirements except for those done prior to exceeding 75% RTP are done at equilibrium conditions whereas for the power ascension surveillance, it is only necessary to have stable conditions.

a. Explain why there is a need for equilibrium conditions during most surveillance; why can't stable conditions suffice?

b. Is there a benefit to defining the same conditions (equilibrium or stable) for conducting all $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillance?

RAI No. 10: Required Actions

Background

In Required Action A (and Required Action B.2) there is a Note that states that Required Action A.4 (Required Action B.2.4) "*shall be* [emphasis added] completed whenever the Condition is entered." However, the completion time for Required Action A.4 (or B.2.4) is "prior to increasing THERMAL POWER above the limit of Required Action A.1 (B.2.1)."

Issue and Request

The Required Actions A.4 and B.2.4 are surveillance requirements. Because of the NOTE accompanying these actions, it is not clear if they must be carried out along with the other Required Actions or whether they can wait until a decision is made to increase THERMAL POWER.

Discuss and clarify the timing of the surveillance to be performed to satisfy both the NOTE and the Required Action B.2.4.

RAI No. 11: Interface of WCAP-17661-P changes with TS 3.2.1A, Heat Flux Hot Channel Factor ($F_Q(Z)$) (CAOC-F_{xy} Methodology)

Background

In addition to TS 3.2.1B and TS 3.2.1C, TS 3.2.1A is included for some CAOC plants. No change is proposed for TS 3.2.1A. It is our understanding that some CAOC plants confirm $F_Q(Z)$ indirectly by measuring $F_{xy}^M(Z)$ and then comparing this measurement to an $F_{xy}(Z)$ limit. In the new formulation, the key factor being measured is also $F_{xy}(Z)$.

Issue and Request

In both TS 3.2.1 A and TS 3.2.1C, the key factor being measured is $F_{xy}(Z)$. However, the TS requirements are different. Some of the concept used in TS 3.2.1C is not used in TS 3.2.1A: namely, TS 3.2.1A is not modified to use a different operating space and avoid reduction in THERMAL POWER.

a. Delineate the difference between CAOC- F_{xy} Methodology and CAOC-T(z) Methodology to explain why the changes similar to that considered for TS 3.2.1C are not applicable for TS 3.2.1A.

b. For CAOC plants, when $F_Q(Z)$ is not within limit, $F_Q^C(Z)$ will also be outside the limit. Under the proposed changes, Required Actions for TS 3.2.1A and TS 3.2.1C are different. Explain and justify the merits of the differences in the TS.

RAI No. 12: Impact of the proposed changes on TS 3.2.4, Quadrant Power Tilt Ratio (QPTR)

Background

TS 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," provides limits and conditions and associated surveillance requirements for QPTR. As stated in the Bases for Section 3.2.4, the QPTR limits ensure that nuclear enthalpy rise hot channel factor ($F^N_{\Delta H}$) and $F_Q(Z)$ remain below their limiting values by preventing an undetected change in the gross radial power distribution. The QPTR limit of 1.02, at which corrective action is required, provides a margin of protection for both the departure from nucleate boiling ratio and linear heat generation rate contributing to

excessive power peaks resulting from X-Y plane power tilts. A limiting QPTR of 1.02 can be tolerated before the margin for uncertainty in $F_Q(Z)$ and $F^N_{\Delta H}$ is possibly challenged.

Issue and Request

Under the proposed changes, when a different operating space is implemented, QPTR may be affected. Since QPTR provides a margin of protection, assurance is needed that the margin of protection is not being lost or that adequate margin of protection will still be maintained.

a. Discuss the impact of the proposed changes on the QPTR and how the changes may impact the current LCO and SR in TS 3.2.4.

b. If changes are non-negligible, discuss that adequate margin of protection is being maintained.

RAI No. 13: Additional discussion of methodology

Background

The RAOC-T(Z) methodology is presented in different sections in WCAP-17661-P for the reader to understand the methodological issues. Details and example results are given; however, some aspects of the discussion of the methodology to obtain $F_Q^W(Z)$ can be considered lacking.

Issues and Request

Additional discussion on the following aspects is requested in order to fully understand the methodology:

a. Provide the specific assumptions, limitations, implementing procedures, and related guidance associated with the methodology and explain how they have been addressed in defining the new requirements.

b. Discuss the attributes/results of the methodology and relate them to the changes proposed in the Specifications. Discuss each of the changes in the Specifications and their relation to the improved methodology if one exists.

c. Discuss any differences from the results presented for a Westinghouse 4-loop plant that might be expected for different designs.

RAI No. 14: Adjustment factor for the radial peaking factor ($A_{XY}(z)$)

Background

Appendix C, "Sample COLR Input for a RAOC Plant," indicates in limit C.2.2.6 that "$A_{XY}(z)$ may be assumed equal to 1.0 or may be determined for specific surveillance conditions using the approved methods listed in TS 5.6.5." This follows discussion contained in Sections 4.3 and 6.4 of the main topical report.

Issue and Request

Regarding Method 2 as described in Licensing Topical Report (LTR) Section 4.3:

a. Provide a comprehensive list of all approved methods that may be used to calculate $A_{XY}(z)$, according to Method 2.

b. Since $A_{XY}(z)$ is a factor used to scale a surveillance value that is used to confirm adherence to a cycle-specific parameter operating limit, its reciprocal could, if applied to the operating limit, be considered a cycle (or, more specifically, situation)-specific scaling factor for a parameter operating limit. The core physics methodology, or computer code, used to calculate this value would need to be referenced in the TS COLR References list, for consistency with Generic Letter 1988-16 guidance.

c. Explain whether $A_{XY}(z)$ is calculated on-site by an implementing licensee, or whether Westinghouse or the PWROG, as supporting vendors, calculate these values.

d. Provide the procedures or engineering guidelines for calculating these values for NRC staff review.

Regarding Methods 3 and 4 as described in LTR Section 4.3:

e. Various passages of text in the LTR appear to acknowledge many shortcomings associated with these methods. For example, Page 6-3 states, "Obviously, this method is somewhat awkward given the large number of values that must be pre-calculated and the need to determine appropriate values for intermediate power levels and rod positions." Explain what benefit offering these methods provide to any implementing licensee: why make this option available?

Regarding $A_{XY}(z)$ in general:

f. The text in Section 4.3 suggests that incorporating an $A_{XY}(z)$ term in the surveillance formulation is optional. For example, Page 4-9 states, "...use of these factors should be an option..." Explain how $A_{XY}(z)$ is applied if its value is greater than 1.

g. Section 6.4 described $A_{XY}(z)$ values for initial power ascension. If the $F_Q^W(z)$ surveillance is not intended to be performed until after a period of equilibrium operation after exceeding a threshold power level, explain why the $A_{XY}(z)$ factors are necessary or desired for initial power ascension.

Program Management Office
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

WCAP-17661- P/NP, Revision 1
Project Number 694

September 13, 2016

OG-16-273

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Subject: PWR Owners Group
Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795

References:

1. Letter OG-13-427, "Submittal of WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated January 2, 2014

2. NRC Letter of Acceptance for Review of PWROG Topical Report WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 1, 2014

3. NRC Letter for Request for Additional Information RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated December 24, 2014 (TAC NO. MF3348)

On January 2, 2014, in accordance with the Nuclear Regulatory Commission (NRC) Topical Report (TR) program for review and acceptance, the Pressurized Water Reactor Owners Group (PWROG) requested formal NRC review and approval of WCAP-17661-P/NP, Revision 1, for referencing in regulatory actions (reference 1). Upon NRC review of the TR, the NRC staff has determined that additional information is needed to complete the review per letter dated December 24, 2014 (reference 3).

Enclosed please find the PWROG response to the NRC Request for Additional Information (RAI) Questions and a revised markup of Technical Specification (TS) 3.2.1B and 3.2.1C.

Enclosed are:

- Three copies of Response to NRC Request for Additional Information (RAI) Questions regarding Pressurized Water Reactor (PWR) Owners Group WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications" and the proposed changes to WCAP-17661-P/NP, Revision 1 (Proprietary). (Enclosure 1)
- One copy of Response to NRC Request for Additional Information (RAI) Questions regarding Pressurized Water Reactor (PWR) Owners Group WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications" and the revised markup of Technical Specification (TS) 3.2.1B and 3.2.1C. (Non-Proprietary). (Enclosure 2)

Also enclosed is Westinghouse letter CAW-16-4470, the accompanying affidavit, Proprietary Information Notice, and Copyright Notice.

The enclosed RAI Response (Enclosure 1) contains information proprietary to Westinghouse Electric Company LLC; it is supported by an affidavit signed by Westinghouse, owner of the information. The affidavit sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b) (4) of Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that this information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the copyright or proprietary aspects of the information listed above or supporting Westinghouse affidavit should reference CAW-16-4470 and should be addressed to Mr. James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company LLC, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066. Correspondence related to this transmittal should be addressed to:

Mr. W. Anthony Nowinowski, Program Manager
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

If you have any questions, please do not hesitate to contact me at (205) 992-7037 or Mr. W. Anthony Nowinowski, Program Manager of the PWR Owners Group, Program Management Office at (412) 374-6855.

Sincerely yours,

Norman J. Stringfellow

Jack Stringfellow, COO & Chairman
PWR Owners Group

NJS:CH

cc: PWROG Licensing Subcommittee (Participants of PA-LSC-0795)
PWROG PMO
PWROG Steering and Management Committee
J. Gresham, Westinghouse
J. Bosma, Westinghouse
E. Mercier, Westinghouse
J. Andrachek, Westinghouse
J. Moorehead, Westinghouse
M. Hone, Westinghouse
J. Brown, Westinghouse
J. Rowley, US NRC

Enclosure 1: PWROG Request For Additional Information Response (Proprietary)
Enclosure 2: PWROG Request For Additional Information Response and revised markup of Technical Specification (TS) 3.2.1B and 3.2.1C (Non-Proprietary)
Enclosure 3: Affidavit for Withholding, CAW-16-4470 (Non-Proprietary) with accompanying Affidavit, Proprietary Information Notice and Copyright Notice

Attachment 2

RAI Responses for WCAP-17661-P/ WCAP-17661-NP, Revision 1

RAI Responses for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (Non-Proprietary)

RAI No. 1: Required Actions when both $F_Q^C(z)$ and $F_Q^W(z)$ exceed limits

Background

Under the proposed change for both relaxed axial offset control (RAOC) heat flux hot channel factor ($F_Q(Z)$) Surveillance (TS 3.2.1B) and constant axial offset control (CAOC) $F_Q(Z)$ Surveillance (TS 3.2.1C), Required Actions are now different for Condition A and B. When $F_Q^C(Z)$ is not within limits, reduction of THERMAL POWER is required along with reduction of setpoints and performance of Surveillance Requirement (SR) 3.2.1.1 and SR 3.2.1.2. Whereas, when $F_Q^W(Z)$ is not within limits, two alternative actions may be applicable. Required Action B.1 requires implementation of a different operating space and if an appropriate operating space cannot be implemented, reduction of THERMAL POWER and setpoints and performance of SR 3.2.1.1 and SR 3.2.1.2 are required. The proposed change in Required Action when $F_Q^W(Z)$ exceeds limits is intended to avoid THERMAL POWER reduction through implementation of a different operating space (Required Action B.1).

Issue and Request

Under the proposed change, when $F_Q^C(Z)$ is within limits and $F_Q^W(Z)$ is not within limits, a different operating space may be implemented and a THERMAL POWER reduction will not be required. However, when both $F_Q^C(Z)$ and $F_Q^W(Z)$ are not within limits, Required Action for $F_Q^C(Z)$ will require reduction of THERMAL POWER. The corresponding evaluation and action for $F_Q^W(Z)$ require clarification. For example, Condition A ($F_Q^C(Z)$ not within limit) requires reduction of THERMAL POWER greater than or equal to (≥) 1 percent (%) for each 1% $F_Q^C(Z)$ exceeds the limit, but Condition B ($F_Q^W(Z)$ not within limit) may require reduction of THERMAL POWER which may be evaluated for 5% decrements in the core operating limit report (COLR). Also, implementation of Required Action B.1 is unclear since the action does not involve reduction of THERMAL POWER.

a. Provide a complete explanation and justification for the THERMAL POWER actions that will be taken when *both* $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits including how the COLR evaluations will be used. Discuss the compatibility of actions for $F_Q^C(Z)$ and $F_Q^W(Z)$ and the supporting evaluations in the COLR.

b. Based on the discussion and the need for clarity of the Required Actions when both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed limits, discuss the need for a NOTE in the Required Action column that may be useful for the operators in abiding by these specifications.

Response to RAI No. 1:

Background Information:

During the power distribution measurements taken during power ascension after a refueling, the plant is still conditioning the fuel for full power operation and is not ready to perform the type of load follow power maneuvers that could challenge the F_Q limit. The measured $F_Q^C(Z)$ from power distribution measurements taken at less than 75% RTP after a refueling is used to confirm that the core is loaded correctly and is behaving consistently with predictions. The $F_Q^C(Z)$ obtained from these measurements will normally have ample margin to the F_Q limit, because the measurements are performed at steady state low power conditions, and the core has been designed to meet the F_Q limit under transient conditions at 100% RTP. If $F_Q^C(Z)$ exceeds the F_Q limit, which is an extremely rare occurrence, the core is in a current operating state where the peak power density is greater than the maximum value assumed in the safety analysis, and the Technical Specification (TS) Actions for Condition A would be implemented. $F_Q^W(Z)$ represents the most limiting transient operation within the allowed AFD limits, i.e., all the extreme cases of frequent core power ramping up and down (load follow) to meet the power demand. These types of power maneuvers are not permitted until the fuel is conditioned to full power operation. Even after the fuel is fully conditioned for full power operation, most plants do not load follow, and operate in the base load mode of operation. If $F_Q^W(Z)$ exceeds the F_Q limit, the core is not currently operating in a condition that exceeds the bounds of the safety analysis. Rather, an $F_Q^W(Z)$ violation indicates that the next 31 EFPD of potential transient operation within the allowed AFD operational space cannot be supported, and the Technical Specification (TS) Actions for Condition B would be followed.

Although the example COLRs in Appendices C and F of WCAP-17661-P identify the F_Q limits separately for $F_Q^C(Z)$ and $F_Q^W(Z)$, the practice for Westinghouse NSSS plants is to define the F_Q limit as the same function for both $F_Q^C(Z)$ and $F_Q^W(Z)$. The F_Q limit is based on the peak local power density assumed in the plant safety analysis. Therefore, there is effectively only one F_Q limit that is applicable to both $F_Q^C(Z)$ and $F_Q^W(Z)$.

Response to 1a:

Since $F_Q^W(Z)$ is always greater than $F_Q^C(Z)$ in any single power distribution measurement, and the applicable COLR F_Q limits are the same, any situation where $F_Q^C(Z)$ exceeds the F_Q limit will result in $F_Q^W(Z)$ exceeding the limit as well.

Clearly, if $F_Q^C(Z)$ exceeds the COLR F_Q limit, this requires a more immediate corrective response than if only $F_Q^W(Z)$ exceeds the limit. Hence, the TS Completion Time for completing the THERMAL POWER reduction in Required Action A.1 is only 15 minutes. In the situation where only Condition B ($F_Q^W(Z)$ not within limit) is entered, the Completion Time for the associated Required Actions B.1 or B.2.1 is 4 hours.

Therefore, if both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, Required Action A.1 will be completed first due to the 15 minute Completion Time. Once the power level is reduced below that specified by Required Action A.1, the current operating peak power density will be restored to less than the value assumed in the safety analysis. However, this Required Action may not ensure that the $F_Q^W(Z)$ limit is met.

New Required Actions for Condition B are proposed to either implement a new operating space or a reduction in THERMAL POWER, and are required in order to ensure compliance with the $F_Q^W(Z)$ limit during future operation under transient conditions. The COLR will provide the available options in terms of implementing a new operating space or a new limit on the maximum *allowed* THERMAL POWER for the purpose of restoring compliance with the $F_Q^W(Z)$ limit. An important distinction between Required Actions A.1 and proposed B.2.1 is that Required Action A.1 requires a reduction of the current operating power level, regardless of what that current operating power level is at the time the surveillance is performed, while proposed Required Action B.2.1 establishes a new THERMAL POWER limit which is less than the RATED THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

A revised markup of the Bases for TS 3.2.1B and 3.2.1C that contains the paragraph above, is included in Attachments 4 and 6 to the RAI responses.

Response to 1b:

The Required Actions for Conditions A and B are different because of the differences in both the immediate severity associated with violating the $F_Q^C(Z)$ limit, versus the $F_Q^W(Z)$ limit, and because there will be significant differences in the amount of margin needed to restore compliance with their respective F_Q limits. In situations where both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed the COLR F_Q limits, compliance with both limits must be restored. Therefore, it is necessary to comply with the Required Actions associated with both Conditions A and B. There is no fundamental incompatibility between the Required Actions for Conditions A and B, since both sets of Required Actions can be met within their associated Completion Times. Since both Conditions A and B require the completion of both SR 3.2.1.1 and SR 3.2.1.2 prior to increasing power above their respective power limits, this ensures that both $F_Q^C(Z)$ and $F_Q^W(Z)$ are assessed and restored to compliance with their respective limits, in the event that either, or both of those parameters exceed their F_Q limit. Therefore a clarifying NOTE to the Required Actions is not necessary.

RAI No. 2: Need to perform SR 3.2.1.2 when $F_Q^C(Z)$ not within limit following refueling prior to THERMAL POWER exceeding 75% rated thermal power (RTP)

Background

Under the proposed change for SR 3.2.1.2, "Verify $F_Q^W(Z)$ is within limit," the first frequency is revised whereby instead of conducting the surveillance "Once after each refueling prior to THERMAL POWER exceeding 75% RTP [rated thermal power]" the requirement will be "Once after each refueling within [24] hours after achieving equilibrium conditions *after* [emphasis added] THERMAL POWER exceeds 75% RTP." This change makes the SR for $F_Q^C(Z)$ and $F_Q^W(Z)$ different, i.e., following refueling, $F_Q^C(Z)$ is checked prior to exceeding 75% RTP whereas $F_Q^W(Z)$ is checked after exceeding 75% RTP. The primary justification for not conducting the surveillance for $F_Q^W(Z)$ below 75% RTP is that, during power ascension, $F_Q^W(Z)$ calculations are not reliable at such power levels.

Issue and Request

The justification for not conducting the $F_Q^W(Z)$ surveillance following refueling prior to exceeding the 75% RTP seems valid and appropriate. However, because of the change, an apparent contradiction is noted. Condition A, $F_Q^C(Z)$ not within limit, may occur prior to THERMAL POWER exceeding 75% RTP. Required Action A.4, "Perform SR 3.2.1.1 and SR 3.2.1.2," will involve unnecessary performance of SR 3.2.1.2.

Provide either an explanation or correction for this situation.

Response to RAI No. 2:

In response to this RAI, the **bold** text will be added to the Note for Condition A and will read as follows:

............NOTE................

Required Action A.4
shall be completed
whenever this Condition
is entered. **SR 3.2.1.2 is not required**
to be performed if this Condition is entered
prior to THERMAL POWER
exceeding 75% RTP after a
refueling.

A revised markup of TS 3.2.1B and 3.2.1C is included in Attachments 3 and 5 to the RAI responses.

RAI No. 3: Changes to SR 3.2.1.2

Background

Section 3.2.5 states (Page 3-16):

> The first Frequency for SR 3.2.1.2 [currently requiring performance of $F_Q^W(Z)$ surveillance "Once after each refueling prior to THERMAL POWER exceeding 75% RTP"] will be changed to state that $F_Q^W(Z)$ must be verified to be within its limit following each refueling within 24 hours after achieving equilibrium conditions after thermal power exceeds 75% RTP... This change is justified since initial startups following a refueling are slow and tightly controlled due to startup ramp rate limitations and fuel conditioning requirements. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit. Also, core power distribution measurements taken at low powers (< 50% RTP) to confirm that the core is loaded properly will provide ample indication that the core is operating consistent with expectations. The new Frequency will ensure that verification of $F_Q^W(Z)$ is performed within a reasonable time period and prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

Page B-1 provides a BASES[1] definition of equilibrium conditions: "being at a stable reactor power (i.e., within plus or minus (±) 1% RTP) and at stable axial flux conditions (i.e., with an axial flux difference variability of± 1% over the previous 24 hours."

Issue and Request

It is not clear that the "new Frequency will ensure that verification of $F_Q^W(Z)$ is performed... *prior to extended non-equilibrium* [emphasis added] operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged," because the new surveillance requirement would permit operation above 75% RTP, *prior to achieving equilibrium conditions*, without performing an initial surveillance. Therefore, as acknowledged in the proposed BASES, "In the absence of these Frequency conditions (discussed above) it is possible to operate for 31 EFPD without verification of $F_Q^W(Z)$."

The current version of the SR establishes an unambiguous requirement to verify $F_Q^W(Z)$ prior to exceeding 75% RTP and generally every 31 EFPD thereafter (or in accordance with the Surveillance Frequency Control Program). The improved TS should also establish an unambiguous requirement to perform an initial surveillance, followed by periodic surveillances on an appropriately justified frequency.

a. Provide analyses of past data of initial surveillance of $F_Q^W(Z)$ prior to exceeding 75% RTP following a refueling to demonstrate that surveillance at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment.

---

[1] NRC staff reviews the proposed BASES for information only and issues requests to obtain clarification and improve the interpretability of the proposed TS; however, plant-specific BASES are administratively controlled and the NRC staff does not intend to extend approval to the BASES provided in WCAP-17661-P Appendices, or to any plant proposing to implement WCAP-17661-P.

b. Justify the 24 hours for completing the surveillance after achieving the equilibrium condition, particularly since 24 hours has elapsed to establish an equilibrium condition.

Response to RAI No. 3:

Response to 3a:

Historically, the issue and difficultly associated with performing $F_Q^W(Z)$ surveillances at reduced power levels has been the fact that the predicted surveillance factors used in the current methodology to convert the measured $F_Q^C(Z)$ into $F_Q^W(Z)$ (i.e., the W(Z) functions) have been generated assuming that the surveillance is performed at 100% RTP, with all control rods fully withdrawn from the core. The denominator of the W(z) function is currently defined as the predicted steady state $F_Q(Z)$ distribution at the plant conditions when the surveillance is performed, times the power level at the plant conditions when the surveillance is performed (see Equation 3-9 on page 3-3 of WCAP-17661-P). In order to perform an accurate $F_Q^W(Z)$ surveillance at reduced power levels during the initial startup following a refueling, using the current F_Q surveillance methods, it has been necessary to generate specific part power W(Z) functions at the expected plant conditions when the surveillance is performed.

Rather than presenting the results from specific part power flux maps (which would almost always be at non-equilibrium conditions) in response to RAI 3.a, Table RAI-3.1 has been provided below, which demonstrates the magnitude of the correction factors that have historically been needed for a typical plant to convert a full power beginning of cycle W(Z) function into a part power W(Z) function. These correction factors account for both the change in relative power when the surveillance is performed, and the predicted change in the steady state axial power shape at reduced power levels. Therefore, in order to generate accurate W(Z) corrections, a transient simulation of the startup must be performed in advance, to simulate the control rod motion and transient xenon conditions expected during the startup. Since the resulting corrections are highly sensitive to control rod position and xenon, any differences between the timing of the actual startup and the simulated startup can result in large errors in the surveillance results, if not corrected prior to the performance of the $F_Q^W(Z)$ surveillance.

The revised F_Q surveillance formulation (defined in Equations 5-1 and 5-2 on page 5-1 of WCAP-17661-P) for RAOC plants significantly reduces the overall sensitivity of the $F_Q^W(Z)$ surveillance to the power level of the surveillance. The sensitivity to the predicted steady state axial power distribution is completely eliminated, and the core relative power term is incorporated directly into the surveillance equations, and is not part of the predicted surveillance factor data. However, there is still some sensitivity present in the new F_Q surveillance formulation to the plant conditions when the surveillance is performed, and this is represented by the $A_{XY}(Z)$ term (defined in Equation 4-35 on page 4-10 of WCAP-17661-P). Tables 4-3, 4-4, 4-5, and 4-6 in WCAP-17661-P demonstrate the sensitivity of the $A_{XY}(Z)$ term to the relative power when the surveillance is performed, and the lead control rod bank position.

Similarly, for CAOC plants, the new F_Q surveillance formulation is less sensitive to surveillances performed at reduced power conditions, and the analogous correction term applied is called $A_Q(Z)$, which is defined in Equation 7-10 on page 7-3 of WCAP-17661-P. Table 7-1 in WCAP-17661-P shows typical values of $A_Q(Z)$ for surveillances performed at 90% RTP.

Response to 3b:

As noted in Section 5.5 of WCAP-17661-P, the Frequency for performing the initial Surveillance Requirement (SR 3.2.1.2) for $F_Q^W(Z)$ following a refueling that is contained in some plant's Technical Specifications is "within 12 hours of achieving equilibrium conditions *after* [emphasis added] THERMAL POWER exceeds 75% RTP." During a controlled startup following a refueling, the plant is in a startup and testing phase, and is not ready to perform the type of load follow power maneuvers that could challenge the $F_Q^W(Z)$ limit until the fuel is conditioned. The current fuel conditioning limits are implemented to prevent pellet clad interaction (PCI) for current Westinghouse fuel. The fuel conditioning limits restrict the rate at which THERMAL POWER can be increased above [ ]^{a,c}% RTP following a refueling outage, and institute minimum hold times at power levels between [ ]^{a,c}% and [ ]^{a,c}% RTP. For fuel to be conditioned above [ ]^{a,c}% RTP, the plant must have operated in the current cycle at or above the conditioned power level for at least [ ]^{a,c} cumulative hours out of the last [ ]^{a,c} days of power operation. These limitations, combined with the time required to perform a complete flux map with the movable incore detector system make it difficult to achieve true equilibrium conditions and complete the $F_Q^W(Z)$ surveillance within 12 hours during a startup following a refueling. While it is recognized that specific fuel conditioning limits may change in the future, it would still be necessary to condition the fuel after a refueling outage before the type of load follow operation which could challenge the $F_Q^W(Z)$ limit would be permitted.

Plants implement fuel conditioning startup limitations for the first startup after a refueling outage.

In the event the plant were held at a THERMAL POWER greater than or equal to 75% RTP but less than 100% RTP for an extended period after a refueling, the $F_Q^W(Z)$ surveillance would be required within 24 hours of achieving equilibrium conditions at the reduced THERMAL POWER. Thus, if the fuel were conditioned to a lower power level, such that transient operation could be performed at or below the fuel conditioned power level, the $F_Q^W(Z)$ surveillance that was performed after reaching equilibrium at these conditions would conservatively justify the transient operation.

Sustained operation at less than 75% RTP after a refueling would be permitted for up to 31 EFPD before an $F_Q^W(Z)$ surveillance was performed. However, the plant would still be restricted by the fuel conditioning limits for performing unrestricted transient operation above the current fuel conditioned power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement (i.e., to perform SR 3.2.1.1 and 3.2.1.2), while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented.

A discussion was added to the Bases for TS 3.2.1B and TS 3.2.1C for SR 3.2.1.1 and SR 3.2.1.2 that incorporates the justification for the 24 hours allowed to perform these Surveillances.

Revised TS Bases markups that reflect this change are included in Attachments 4 and 6 to the RAI Responses.

It should be noted that other Technical Specification SRs contain a Note that allows deferral of the Surveillance, typically for 24 hours, until plant conditions that are required to perform the Surveillance can be achieved, in order for an accurate Surveillance to be performed. Some examples are the Notes to SRs 3.3.1.2, 3.3.1.3, 3.3.1.6, 3.3.2.10, 3.4.1.4, and 3.4.5.3.

Table RAI-3.1 Typical Part Power W(Z) Correction Factors C(Z)

a,c

RAI No. 4: Treatment of uncertainties in $F_Q^C(Z)$ and $F_Q^W(Z)$ determination and in defining the requirements

Background

One of the multiplicative factors that determines $F_Q^C(Z)$ and $F_Q^W(Z)$ is the uncertainty U_F which accounts for measurement and manufacturing uncertainties. It is typically 1.0815 (Page 3-2), which is the result of multiplying a measurement uncertainty of 1.05 by a manufacturing uncertainty of 1.03. The sample COLR input given in Appendices C and F do not refer to U_F but do use 1.0815 as one the factors determining the above $F_Q\{Z)$ quantities. It is not stated if these uncertainties represent 1-sigma or a 95/95 uncertainty. The use of a measurement uncertainty is obvious but the use of an uncertainty to account for manufacturing tolerances is less clear.

Another factor defining $F_Q^W(Z)$ is the T(z) function. According to the statement made with respect to Equations 2-23 and 2-24, the T(z) functions are derived with "appropriate uncertainties."

Issue and Request

A better discussion of the treatment of uncertainties in the methodology, in the calculated parameters, and how they are addressed in defining the requirements is appropriate.

a. Explain how uncertainties are taken into account in defining the $F_Q^C(Z)$ and $F_Q^W(Z)$ that are monitored.

b. It is understood that part of the uncertainty is the result of the surveillance measurement of planar radial peaking factor (Fxv(Z)) and part the result of the analysis to obtain T(z). The T(z) uncertainty is expected to be incorporated into the tabulation of these functions but the measurement uncertainty would be explicitly given in the COLR if it is a function of the particular reactor and fuel cycle or explicitly given and explained in the topical report if it is a generic number. Explain which of these options is being recommended and why.

Response to RAI No. 4:

Response to 4a:

The generic measurement uncertainty associated with F_Q measurements performed using the standard moveable incore detector flux mapping system was developed and approved by the NRC in WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties." Similarly, the generic engineering uncertainty associated with Westinghouse fuel manufacturing tolerances has been in use since WCAP-8385 "Power Distribution Control and Load Following Procedures," was approved by the NRC in a letter from J. F. Stolz (NRC) to C. Eicheldinger (Westinghouse), "Safety Evaluation of WCAP-8385 (P) and WCAP-8403 (NP)," dated January 31, 1978. These values represent 95/95 uncertainties. The engineering uncertainty for manufacturing tolerances is applied to measurements of $F_Q(Z)$, because analytically derived pin factors are used to obtain the "measured" pin powers from the measured assembly powers. These pin factors are based on calculations that assume nominal design values of pellet enrichment, density, and burnable absorber loading. The engineering uncertainty addresses the effects of variations in the as-built fuel pellet from nominal design values.

The specific uncertainties used at each plant are typically discussed in the Technical Specification Bases for SR 3.2.1.1 and in the Nuclear Design section of the plant's Updated Final Safety Analysis Report, as required by NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*. The use of 1.05 for the measurement uncertainty and 1.03 for the engineering uncertainty in this topical report is only for the purpose of illustrating typical generic values that are used in most Westinghouse NSSS plants. Plant specific uncertainty values may be different than the generic values for a variety of reasons, including the use of a different incore detector system design.

As discussed with respect to Equations 2-23 and 2-24 in WCAP-17661-P, the calculational uncertainties used in confirming that the transient F_Q limits will be met for a given cycle are also generically determined and approved in WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties." A 5% (i.e., 1.05) 95/95 calculational uncertainty and the same 3% (i.e., 1.03) 95/95 engineering uncertainty that are applied to the measurement, are also applied to the maximum calculated transient F_Q*P_{rel} values during the nuclear design analysis, when confirming that the F_Q limit is met. As new nuclear design methods are developed and licensed (approved by the NRC), the generic 5% calculational uncertainty is confirmed to remain bounding or is increased as necessary.

Response to 4b:

No explicit uncertainties have been defined or proposed for the T(Z) surveillance factors. The following discussion is provided in support of this approach.

T(Z) is a factor of the total $F_Q^W(Z)$. During the performance of SR 3.2.1.2, $F_Q^W(Z)$ is increased by the 95/95 measurement and manufacturing tolerance uncertainties prior to comparing it to the F_Q limit, as discussed above in the response to RAI 4a. In the case where the generic 5% measurement uncertainty in WCAP-7308-L-P-A is applied to the $F_Q^W(Z)$, the actual 95/95 uncertainty associated with the measured $F_{XY}(Z)$ distribution from the incore detector system is only [ ]^{a,c}, as specified in Table 2-1 (Addendum 1, Revision 1) of WCAP-7308-L-P-A. The

application of the 3% manufacturing tolerance uncertainty will also result in some additional conservatism, since the only reason this uncertainty is applied to the measurements is because of the use of the analytically derived pin factors that were based on nominal design characteristics. Any significant change in the assembly average power distribution caused by fuel manufacturing tolerances will be captured directly in the measured power distribution.

The measured steady state $F_{XY}(Z)$ distribution is the only actual measured data provided during the performance of SR 3.2.1.2 in TS 3.2.1B. The measured steady state $F_{XY}(Z)$ distribution is effectively divided by the predicted steady state $F_{XY}(Z)$ distribution at the surveillance condition, which is contained in the denominator of the T(Z) function. As stated on page 4-3 of WCAP-17661-P, the intent of this approach is to normalize the predicted $F_{XY}^{HFP}(Z)$ term shown in Equation 4-4, to account for the effects of measured radial tilts or some other underprediction of the limiting radial peaking factors. Since the predicted radial peaking factors are normalized to measured values (including the application of the conservative measurement and manufacturing uncertainties), the only remaining component of the $F_Q^W(Z)$ surveillance which comes from the calculations is the transient axial $P^{Tr}(Z)$ term (contained in the T(Z) numerator). As discussed in Section 8.4 in WCAP-7308-L-P-A, the predicted axial peaking factor uncertainty with 95/95 statistics is [ ]^{a,c}% . If one statistically combines the independent uncertainty factors associated with the measured radial peaking factors [ ]^{a,c}% and the calculated axial peaking factors [ ]^{a,c}%, the total 95/95 uncertainty associated with this approach is [ ]^{a,c}%, which is bounded by the application of the generic 5% measurement uncertainty to the $F_Q^W(Z)$ result. It is therefore concluded that the $F_Q^W(Z)$ surveillance includes sufficient uncertainty (via application of the 5% measurement uncertainty) to account for any additional uncertainty associated with the calculated T(Z) factor.

Additionally, it should be noted that the T(Z) function is developed at each axial elevation (Z) by taking the maximum result of a large number of Condition I transient simulations (see Equation 4-30 in WCAP-17661-P). The result is a bounding function that is comprised of pointwise worst results from several of the most limiting transient shapes. For example, the T(Z) at an elevation of 2-feet will likely be from a negatively skewed axial power shape, while the T(Z) at 10-feet will likely be from a positively skewed axial power shape. T(Z) values near the middle elevations may be from either type of axial shape. Assuming the calculational uncertainty associated with P(Z) is random in nature, the transient P(Z) at any given axial location associated with any given calculated axial power shape may be overestimated or underestimated. By selecting the maximum value at each Z, the selection process favors results where the calculated T(Z) is more likely to be overestimated. Thus the [ ]^{a,c}% uncertainty allowance for the predicted P(Z) included in the total FQ uncertainty allowance of 5% is highly conservative for T(Z).

RAI No. 5: New Required Action B.1 requiring implementation of a RAOC/CAOC operating space

Background

Under the proposed change, Required Action B.1 states:

> Implement a RAOC/CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within its limits.

As stated on Page 3-14 of WCAP-17661-P,

> Pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be included in the COLR and characterized by transient (T(z) functions) which, in conjunction with measured radial peaking factors, may be used to quantify margin and ensure compliance with the LCO for future non-equilibrium operation. Analogous to the CAOC operating space concept..., a RAOC operating space is a unique combination of AFD [axial flux difference] operating space envelope and control rod bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient F_Q margin, maximum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the required reductions will be included in the COLR.

In addition, as part of the change for both RAOC and CAOC plants, the NOTE in Condition B stating that Required Action B.4 shall be completed whenever this Condition is entered is deleted. A NOTE in the Required Action column under Required Action B.2.1 is entered stating that Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed.

(Both B.4 in the previous version and B.2.4 in the revised version are the same Required Action, "Perform SR 3.2.1.1 and SR 3.2.1.2)." In effect, SRs will no longer be applicable when Required Action B.1 is implemented.

Issue and Request

Based on the analysis presented, the use of a different operating space is generally an appropriate approach to gain margin improvement. However, if changing the rod insertion limits (RILs) is part of the new operating space AND that requires movement of control rods to comply, then this approach puts the reactor into a new operating condition.

In addition, in order to understand if the new operating space will provide the needed margin, it is necessary for the reactor engineer to evaluate $F_Q^W(Z)$ using the T(z) for different operating spaces. This must be done within four hours, the TS completion time.

If movement of control rods was required, a reevaluation of $F_Q^C(Z)$ and $F_Q^W(Z)$ will be required to assure that TS requirements are being met. In other words, the NOTE may apply to B.1 for such situations.

Explain the use of Required Action B.1 incorporating the response to the following:

a. Explain what would be done if Required Action B.1 is carried out and requires movement of control rods.

b. Explain if in addition to the T(z) tables there will be tables to show the margin improvement as a function of axial position or some other scheme in the COLR to make it easier for the reactor engineer to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary.

c. Explain the deletion of the NOTE to perform SR 3.2.1.1 and SR 3.2.1.2 under required Action B.1.

d. Discuss clearly the specific actions (e.g., how are the rod insertion limits imposed) that will be undertaken by the operator in implementing the new operating space and consequently what would constitute a violation of this required action.

Response to RAI No. 5:

Response to 5a and 5c:

If control rod motion is needed as a result of entering Condition B and performing Required Action B.1, the fundamental measured power distribution will change as a result. Based on past operating experience, entry into Condition B is expected to be an unlikely occurrence. Most $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances are performed at 100% RTP with the control rods near fully withdrawn, so the institution of a new rod insertion limit after entry into Condition B would not result in control rod motion in most cases. It is also considered very unlikely that the withdrawal of control rods (if necessary) would result in an increase in the measured radial peaking factors, $F_{XY}(Z)$. This conclusion is based on current core design practices as demonstrated by historically observed trends in predicted $F_{XY}(Z)$ with control rod insertion for most core designs. However, it is considered plausible that if the measured $F_{XY}(Z)$ peak happened to occur adjacent to or in an assembly containing an inserted control rod, that withdrawal of that control rod could potentially increase the resulting $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values. It is also possible that a revision to the allowed AFD band associated with implementing Required Action B.1 could result in either control rod withdrawal or insertion in some cases, in order to obtain and maintain the AFD within the allowed operating band.

Therefore SR 3.2.1.1 and SR 3.2.1.2 should be performed if the implementation of Required Action B.1 results in the need to move control rods. The Required Actions for Condition B in both Technical Specifications 3.2.1.B and 3.2.1.C will be revised to require the performance of SR 3.2.1.1 and SR 3.2.1.2 if the implementation of a new operating space results in the need to move the control rods in order to comply with a new rod insertion limit. A Completion Time of 72 hours is proposed to ensure that the plant has time to restore equilibrium conditions in the event that control rod motion results in a transient condition. Proposed Required Action B.1 would become Required Action B.1.1 in both Technical Specifications, and a new Required Action B.1.2 would be added to perform SR 3.2.1.1 and 3.2.1.2 with a required Completion Time of 72 hours. A markup of TS 3.2.1B and TS 3.2.1C is provided as Attachments 3 and 5 to the RAI responses.

Response to 5b:

Margin improvement tables are not required to be included in the COLR, since the margin can be determined by applying the new surveillance factors associated with the revised operating space to the power distribution measurement, and since a new Required Action will be added to perform SR 3.2.1.1 and 3.2.1.2, as discussed above, if control rod motion is required as a result of implementing the new operating space. Performing SR 3.2.1.1 and SR 3.2.1.2 will confirm that the required margin has been restored.

Response to 5d:

If a new rod insertion limit resulted in the need to withdraw control rods, that Required Action (A.2) would be completed within 2 hours of implementing the new rod insertion limit, in accordance with the Required Actions of TS 3.1.6 (Control Bank Insertion Limits), for Condition A (Control Bank insertion limits not met). Since the new operating space may not be implemented for up to 4 hours, the total allowed time to reposition the control rods would be within 6 hours after the entry into LCO 3.2.1 Condition B. If the control rods were not repositioned to above the insertion limits associated with the new rod insertion limit within 6

hours of initially identifying the $F_Q^W(Z)$ violation, Condition C of TS 3.1.6 would be entered and the Required Action is to be in Mode 2, with keff < 1 in 6 hours. Since the revised operating space that will be implemented will be contained in the COLR, the implementation of the revised operating space can be performed by the operator.

The implementation of a License Amendment Request (LAR) includes reviewing the procedures that are affected by the LAR. Prior to implementing a LAR, any affected procedures are revised to reflect the Technical Specification changes in the LAR.

The Technical Specification (TS) Surveillance Requirement (SR) that verifies that the Control Banks are above their insertion limits is implemented via a plant procedure.

SR 3.1.6.2 in NUREG-1431, "Standard Technical Specifications, Westinghouse Plants," states:

"Verify each control bank insertion is within the insertion limits specified in the COLR."

The Frequency of SR 3.1.6.2 in NUREG-1431 is "[12 hours or In accordance with the Surveillance Frequency Control Program.] "

If revised Control Bank Insertion Limits are implemented, as allowed by the revised TS Required Actions that are contained in Attachments A and D of WCAP-17661, the revised Control Bank Insertion Limits would be contained in the COLR.

TS SR 3.1.6.2 requires that each control bank insertion is within the insertion limits specified in the COLR, and the revised Control Bank Insertion Limits that are contained in the COLR would be used to determine that this SR is met.

The instrumentation that is used to satisfy SR 3.1.6.2 is the Demand Position Indication System, which is required to be Operable by TS 3.1.7, "Rod Position Indication,' in NUREG-1431.

The Bases for TS SR 3.1.6.2 in NUREG-1431 state:

"Verification of the control bank insertion limits at a Frequency of 12 hours is sufficient to detect control banks that may be approaching the insertion limits since, normally, very little rod motion occurs in 12 hours."

Therefore the Frequency of TS SR 3.1.6.2 is adequate to ensure that the Control Banks are within their insertion limits during normal operation to ensure that the power distribution and reactivity limits defined by the core design peaking factors and shutdown margin assumptions in the safety analyses are maintained.

The Control Rod Insertion Monitor and associated alarms are not credited for satisfying TS SR 3.1.6.2.

If the transient $F_Q^W(Z)$ limit is not met, and the TS Required Actions that allow a new operating space to be implemented with a different set of control rod insertion limits, those limits (i.e., operating space and control rod insertion limits) will always be more restrictive than the primary analyzed operating space. The core conditions allowed by the new operating space will always be a more restrictive subset of those allowed by the primary (or initial) operating space that is assumed in the safety analyses. This is illustrated by the example operating spaces shown in Figures 6-1, 6-2, and 6-3 in WCAP-17661-P. Thus, the implementation of a new, more

restrictive, operating space to restore the transient $F_Q^W(Z)$ to within its limit, will not result in any impact to any safety analyses.

As discussed above, the initial safety analysis assumptions regarding the control rod insertion limits will continue to be met, since the revised control rod insertion limits are more restrictive.

RAI No. 6: Effect of Crud Induced Power Shift

Background

Currently, any downward trend in margin (as defined by the minimum margin over all axial locations) is accounted for by applying a penalty factor and requiring additional surveillance. This is specified in a note modifying SR 3.2.1.2, which is proposed to be eliminated. This NOTE monitored increases in $F_Q^W(Z)$ from the previous surveillance and required additional surveillances if measurements indicated that the maximum over z of $F_Q^C(Z)/K(Z)$ has increased since the previous evaluation of $F_Q^C(Z)$.

In lieu of this approach, it is proposed that a penalty factor be applied that takes account of the expected change in margin during the next effective full power minutes as a result of normal changes in burnup. This approach eliminates any action due to the concern over crud induced power shift (CIPS). Reasons are given for this (Page 4-18).

One of the arguments presented is that past trends of $F_Q^C(Z)/K(Z)$ may or may not be indicative of future trends. It is justified to remove monitoring of $F_Q^C(Z)/K(Z)$ for indication of future margin trends if it does not provide the required indication.

Request

It is stated (Page 4-18):

> ... given that CIPS develops slowly and characteristically, it is proposed that its effects on peaking factor be evaluated in a timely fashion following its observed onset.

Although the TS is designed to monitor power peaking, it appears that the licensee will now have full discretion as to how monthly trends due to any anomalous behavior are taken into account.

a. Explain how this would actually take place.

b. Provide data from past experience and additional discussion supporting the statement "past measurement trends of $F_Q^C(Z)/K(Z)$ may or may not be indicative of future margin trends."

Response to RAI No. 6:

Response to 6a:

As discussed in Section 4.5 of WCAP-17661-P, the best indicators of CIPS are the observed measured minus predicted axial offset being more negative than -3% beginning at burnups of 4000 to 8000 mwd/mtu, high predicted sub-cooled boiling rates, flux depressions in the upper spans of high power assemblies, and an indication of lithium return following a power reduction.

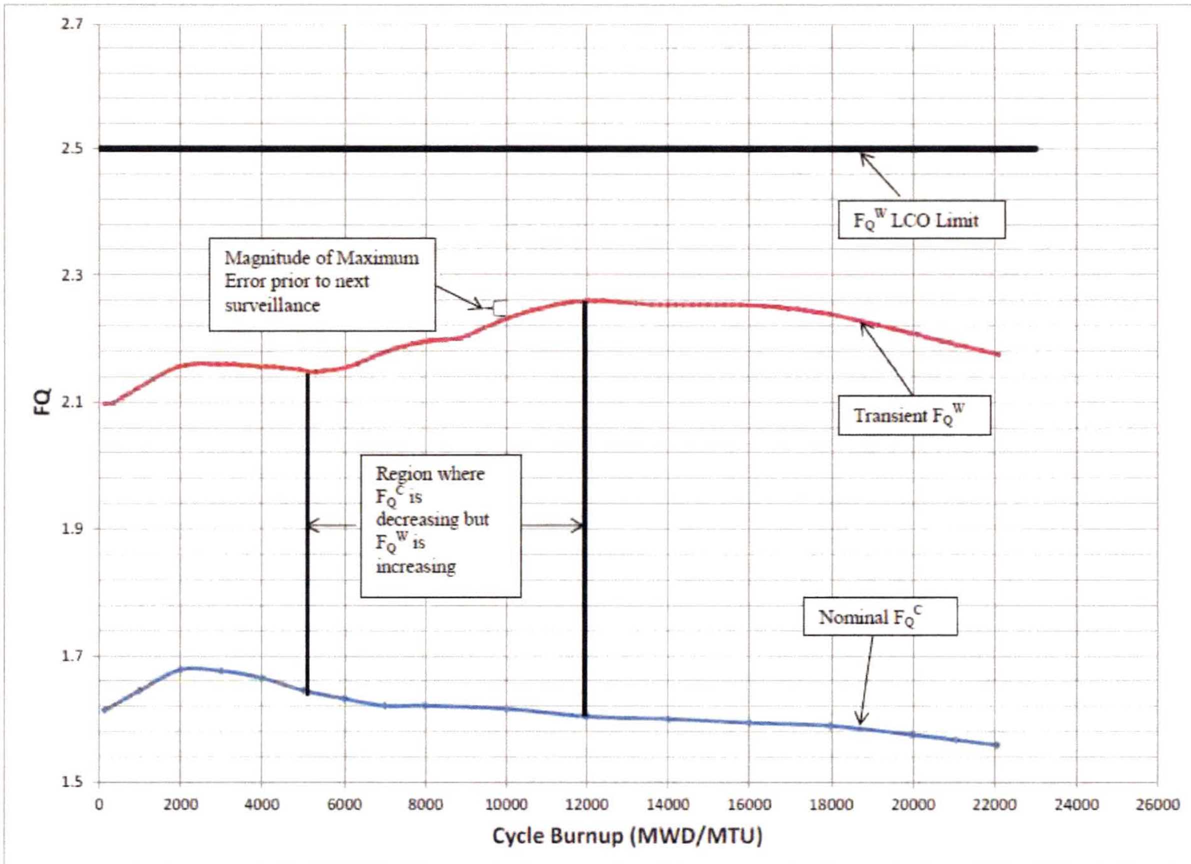
Westinghouse has provided guidance to the industry describing the characteristics of CIPS and other forms of axial offset deviation, and requested to be notified in cases where the measured minus predicted steady state axial offset is more than ±3% in either direction. Nuclear design procedures have been established at Westinghouse both for screening reload cores for CIPS risk, and for evaluating the effect of CIPS on the power distribution surveillance data and other parameters, if it occurs. As noted in Section 4.5 of WCAP-17661-P, both the incidence and magnitude of CIPS events have been significantly reduced, due largely to the addition of CIPS risk to the loading pattern risk assessment process, and advances in predictive capabilities for sub-cooled boiling and crud deposition.

Response to 6b:

An issue has been identified that the use of measured trends in $F_Q^C(Z)$ may not always be indicative of the same margin trend in the measured $F_Q^W(Z)$, particularly when the axial power distribution of the core is in transition from a cosine type shape to a flattened saddle type shape. Figure RAI-6.1 illustrates an example of such a case by comparing the predicted steady state and maximum transient F_Q values for an example cycle.

Furthermore, it must be clarified that the initial onset of CIPS will not necessarily result in observing a decreasing trend in either the $F_Q^C(Z)$ or $F_Q^W(Z)$ margin. The preferential accumulation of boron-containing crud in high power assemblies will tend to decrease the radial peaking ($F_{XY}(Z)$) in the affected elevations of the highest power assemblies. If the nominal predicted AFD is slightly positive, the onset of CIPS may result in the AFD being closer to zero or slightly negative. Both of these factors could result in an increasing trend in margin for $F_Q^C(Z)$, initially. The trend in $F_Q^W(Z)$ is driven largely by the T(Z) or W(Z) surveillance factors, which, as noted in Section 4.5 of WCAP-17661-P, will not include the effects of CIPS if it occurs. Thus, the observation of past trends in margin for either $F_Q^C(Z)$ or $F_Q^W(Z)$ is not very useful in identifying the onset of CIPS. Only in the later stages of a relatively severe CIPS event can it be stated with high confidence that the $F_Q^C(Z)$ margin will be decreasing with burnup.

Figure RAI-6.1 **Comparison of Predicted Trend in $F_Q^C(Z)$ or $F_Q^W(Z)$ as a Function of Cycle Burnup for an Example Plant**



RAI No. 7: Change of Required Action B.2.1 and limitation of THERMAL POWER to < 50% RTP

Background

The improved TS define a new Required Action B.2. When $F_Q^W(Z)$ exceeds its limits, Required Actions B.2.1, B.2.2, B.2.3, and B.2.4 can be implemented instead of Required Action B.1. Required Action B.2.1 limits thermal power to less than RTP by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Action B.2.1 must be entered and THERMAL POWER must be reduced to less than the thermal power specified in the COLR. Also, AFD limits must be reduced by the amount specified in the COLR.

It is also noted that as a practical matter, the number of discrete reduced power level evaluations included in the COLR will be limited to three or less (an individual utility may opt for additional evaluation levels). Also stated in WCAP-17661-P, if the required margin improvement exceeds the level of any pre-analyzed thermal power limits, the COLR will specify that the thermal power is limited to <50 percent RTP. WCAP-17661-P also states that other TS, such as the Nuclear Enthalpy Rise Hot Channel Factor TS, would also require a power level reduction in the presence of such a large anomaly.

Issue and Request

For situations where necessary margin improvement exceeds the level of any pre-analyzed thermal power limits, the requirement to reduce the thermal power to less than 50 percent RTP is not noted in the Technical Specifications (TS) or in the Bases. Since this type of situation means that a very large and unusual core anomaly is present, clear guidance and justification for the actions should be presented.

a. Explain how the required actions in the COLR for Required Action B.2.1 will be sufficient if $F_Q^W(Z)$ is not within limits. For example, will some limit of power to 50% RTP always be imposed and if so, at what point (vis-a-vis margin needed) would that be required.

b. Since the reduction of thermal power to < 50% RTP is a defined parameter applicable to all Westinghouse plants, explain why this requirement should not be included in the TS and/or Bases.

Response to RAI No. 7:

Response to 7a:

As shown in the example COLRs provided in Appendices C and F of WCAP-17661-P, it is intended that the ultimate power reduction specified in the COLR for Required Action B.2.1 will be to less than 50% RTP, when the measured margin improvement required in the $F_Q^W(Z)$ surveillance exceeds the margin gain for the otherwise calculated combinations of THERMAL POWER and AFD limits. The 50% RTP power threshold is consistent with several other Westinghouse Standard Technical Specifications (NUREG-1431). For example, TS 3.2.2 (Nuclear Enthalpy Rise Hot Channel Factor) contains a Required Action that the power be reduced to less than 50% RTP if the $F_{\Delta H}^N$ limit is not met and is not restored to within the limit within 4 hours. TS 3.2.3A (Axial Flux Difference (CAOC Methodology)) allows the AFD to deviate outside the target AFD band with THERMAL POWER < 50% RTP, subject to the accumulation of penalty deviation time. TS 3.2.3B (Axial Flux Difference (RAOC Methodology)) does not apply when THERMAL POWER < 50% RTP. TS 3.2.4 (Quadrant Power Tilt Ratio) does not apply when THERMAL POWER ≤ 50% RTP.

If $F_Q^W(Z)$ exceeds the F_Q limit, the most likely cause will be the measured radial peaking factors ($F_{XY}(Z)$) being higher than predicted in the original nuclear design analysis. The higher measured radial peaking factors will also affect the measurements of the current operating heat flux hot channel factor, $F_Q^C(Z)$, and the nuclear enthalpy rise hot channel factor, $F_{\Delta H}^N$. If the measured radial peaking factors are high enough so that the $F_Q^C(Z)$ limit is not met, the Required Actions for Condition A require the THERMAL POWER to be reduced as much as necessary to restore compliance of the $F_Q^C(Z)$ limit. This would include reducing THERMAL POWER to less than 50% RTP, if the severity of the observed violation was large enough to require that. Thus, in such a case where the COLR power limitations in Required Action B.2.1 result in power being reduced to less than 50% RTP, compliance with the *current operating* heat flux hot channel factor is ensured, via the measured results of the $F_Q^C(Z)$ surveillance, or by meeting the Required Actions for Condition A of TS 3.2.1B or 3.2.1C. Similarly, compliance with the current operating nuclear enthalpy rise hot channel factor is ensured, via the measured results of the $F_{\Delta H}^N$ surveillance, or by meeting the Required Actions of TS 3.2.2. Therefore, the plant will either be measured to be complying with the TS peaking factors LCO limits, or meeting the Required Actions associated with the $F_Q^C(Z)$ and $F_{\Delta H}^N$ limits to restore compliance with the limits for the current operation.

If the transient $F_Q^W(Z)$ is not met, this would only result in the core operating outside the assumed peaking factor basis in the safety analysis if transient operation were to occur, which results in the plant operating at the edge of the allowed operating space. In the event that the THERMAL POWER is reduced to < 50% RTP per Required Action B.2.1, the transient $F_Q^W(Z)$ limit will be met for the following reasons. As shown in equations 2-19 and 2-20 of WCAP-17661-P, the typical F_Q limit is divided by the relative power level down to 50% RTP and then remains constant at lower power levels. Thus the reduction of THERMAL POWER to less than 50% RTP results in doubling the allowed F_Q limit. Furthermore, the potential for transient operation that significantly disturbs the core xenon distribution is significantly reduced if the maximum power of such transients is limited to <50% RTP.

Response to 7b:

The following paragraph was added to the Bases as the first paragraph for Required Action B.2.1 in TS 3.2.1B:

> When FQ W(Z) exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the FQ W(Z) limit, then Required Action B.2.1 must be entered and THERMAL POWER must be limited to less or equal to 50% RTP and AFD limits must be reduced by the amounts specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

The following paragraph was added to the Bases as the first paragraph for Required Action B.2.1 in TS 3.2.1C:

> When FQ W(z) exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. If the more restrictive CAOC operating spaces specified in the COLR are insufficient to ensure margin to the FQ W(z) limit, the THERMAL POWER must be limited to less than or equal to 50% RTP. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

The following paragraph was added to the Bases as the second paragraph for Required Action B.2.1 in TS 3.2.1B and TS 3.2.1C:

> "If the required FQ W(z) margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than 50% RTP will provide additional margin in the transient FQ by the required change in THERMAL POWER and the increase in the FQ limit. This will ensure that the FQ limit is met during transient operation that may occur at or below 50% RTP."

Revised TS Bases markups that reflect this change are included in Attachments 4 and 6 to the RAI Responses.

RAI No. 8: Implementation of 24-Hour Frequency in TS SR 3.2.1.1 and 3.2.1.2

Background

The Section 3.2.4 states (Pages. 3-14 and 3-15):

> In the improved F_Q TS, the second Frequency will be revised to require verification of $F_Q^C(Z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10% RTP , the THERMAL POWER at which $F_Q^C(Z)$ was last verified. This Frequency of 24 hours is contained in some plant Technical Specifications. (for a few plants, no Frequency is specified) and is a reasonable time period in which to perform this verification given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The information is repeated in Sections 5.4 and 8.4 and a similar change is proposed for SR 3.2.1.2, related to surveillance of $F_Q^W(Z)$.

The purpose of bracketed information in Standard Technical Specifications is to denote site-specific information, which must be in conformance with the final safety analysis report as updated. Refer to Chapter 16.0, "Technical Specifications," of NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*, for further details.

Issue and Request

Since Pressurized Water Reactor Owners Group (PWROG) proposes to use WCAP-17661 as a basis to reduce the frequency requirement for these surveillance test intervals, a more thorough technical justification for the change should be provided. The justification should either follow a clearly risk-informed or deterministic approach, rather than provide a qualitative assessment of the likelihood of limiting initial conditions or initiating events.

If risk-informed, the appropriate regulatory guidance should be followed. This would include NRC Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," and RG 1.177, "An Approach for Plant-Specific, Risk-Informed Decision Making: Technical Specifications."

If deterministic, the justification could include consideration of the consequences of a postulated event occurring in a condition in which the extended surveillance interval prevented assurance that operation was within specified limiting conditions, and of additional mitigating features that would ensure that continued operation in such a condition remains otherwise acceptable. Finally, consider whether plant-specific submittal items should be identified, which would justify any facility licensing basis changes required to implement the proposed TS change.

Response to RAI No. 8:

The proposed change allowing the $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances to be performed within 24 hours (instead of 12 hours) after reaching equilibrium conditions after exceeding by > 10% RTP, the THERMAL POWER at which the surveillances were last performed is not a reduction in the frequency requirement. The same number of surveillances will ultimately be performed. If the unit increases THERMAL POWER by 10% or more since the surveillances were last performed, and then reaches equilibrium conditions, SR 3.2.1.1 and SR 3.2.1.2 are required to be performed regardless of the proposed change in the proposed time of 24 hours to complete the surveillance. The proposed change affects only the time allowed to complete the surveillance, not the total number of surveillances that are performed.

A discussion was added to the Bases for TS 3.2.1B and TS 3.2.1C for SR 3.2.1.1 and SR 3.2.1.2 that incorporates the justification above for the 24 hours allowed to perform these Surveillances.

Revised TS Bases markups that reflect this change are included in Attachments 4 and 6 to the RAI Responses.

The proposed change in time allowed to complete the surveillance from 12 hours to 24 hours applies to situations where the $F_Q^C(Z)$ and potentially the $F_Q^W(Z)$ have already been measured at least once at a reduced power level. The observed margins in the previous surveillances will provide assurance that increasing power up to the next plateau will not exceed the F_Q limit, and that the core is behaving as designed. For example, if a previous $F_Q^C(Z)$ measurement was performed at 70% RTP, then there should be greater than 30% margin available to the F_Q limit from the current operating state. This would be expected to be true for any surveillance of $F_Q^C(Z)$ performed above 50% RTP, since the allowed F_Q limit increases by the inverse of the current relative power level in this range of Power Operation. The nature of thermal feedback from increasing fuel and moderator temperatures will reduce the measured $F_{XY}(Z)$ values with increasing power levels. Therefore, the results of the previous $F_Q^C(Z)$ surveillance provide reasonable assurance that continued power ascension to 100% RTP will not result in the actual operating heat flux hot channel factor exceeding the safety analysis limit.

In addition, the observed margin in the $F_{\Delta H}^N$ measurement required by TS 3.2.2 will confirm that the radial peaking factors are behaving as expected prior to increasing power above 75% RTP.

The successful performance of the $F_Q^C(Z)$ and $F_{\Delta H}^N$ surveillances prior to exceeding 75% RTP following each refueling, in conjunction with the controlled power ascension following a refueling due to the fuel conditioning ramp restrictions, provides a very high level of confidence that the initial operation at 100% RTP following a refueling will not exceed the heat flux hot channel factor assumed in the plant safety analysis, while the fuel is being conditioned. As discussed in the response to RAI No. 3, the Westinghouse fuel conditioning guidelines require at least [ ]^{a,c} cumulative hours of operation at a steady state power level in the last [ ]^{a,c} day period in order for the fuel to be considered fully conditioned. Therefore, the $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances will be performed at 100% RTP before the fuel is fully conditioned to 100% RTP operation and the type of load follow power maneuvers are permitted that could result in heat flux hot channel factors which may challenge the F_Q limit.

RAI No. 9: Equilibrium vs Stable Conditions

Background

The SR for $F_Q^C(Z)$ requires a measurement "Once after each refueling prior to THERMAL POWER exceeding 75% RTP." According to the BASES (Page B-1), equilibrium conditions are not required for this measurement but rather stable conditions are required. Both equilibrium and stable conditions require that the power be within ± 1% but for equilibrium, this condition must exist for 24 hours. Equilibrium conditions also require that the AFD be within ± 1% for that 24-hour period but stable conditions just require that the AFD be within ± 0.5% during the period of interest (when the measurement is being done).

Issue and Request

All surveillance requirements except for those done prior to exceeding 75% RTP are done at equilibrium conditions whereas for the power ascension surveillance, it is only necessary to have stable conditions.

a. Explain why there is a need for equilibrium conditions during most surveillance; why can't stable conditions suffice?

b. Is there a benefit to defining the same conditions (equilibrium or stable) for conducting all $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillance?

Response to RAI No. 9:

Response to 9a:

Stable conditions can suffice if necessary for particular surveillances of the $F_Q^C(Z)$ taken during the initial power ascension after a refueling, because these surveillances do not involve the application of analytically calculated surveillance factors, such as T(Z) or W(Z), which assume equilibrium conditions. Thus the only potential source of error introduced in the measurement of $F_Q^C(Z)$ is the effect of transient conditions on the radial power distribution during the measurement, which although small, are not negligible, even if stable conditions are met. In addition, the $F_Q^C(Z)$ measurements taken during power ascension are primarily for the purpose of assuring that the core is behaving as expected and that it is safe to proceed up to the next power plateau.

Measurements taken during equilibrium conditions are preferable, since they are more repeatable, and are consistent with the generation of the surveillance factors that are used in the $F_Q^W(Z)$ surveillance. Thus, the measurements that are taken for the purpose of justifying the next 31 EFPD of operation, including the potential for transient load follow operation, are performed under equilibrium conditions.

The Bases for NUREG-1431 were reviewed to determine whether "equilibrium conditions," was previously discussed in any of the Bases.

The NUREG-1431 Bases for Technical Specification 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," contains the following discussion for "equilibrium conditions," in third sentence of the Bases for Required Action A.3, on Page B 3.2.4-3:

"... Equilibrium conditions are achieved when the core is sufficiently stable at intended operating conditions to support flux mapping..."

Based on this Bases discussion that is contained in the Bases for NUREG-1431, the following sentence was added to the fourth paragraph in the Bases for SR 3.2.1.1 and as the second paragraph in Insert 4 in the Bases discussion for SR 3.2.1.2 in the Bases for TS 3.2.1B and TS 3.2.1C:

"Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance."

Revised TS Bases markups that reflect this change are included in Attachments 4 and 6 to the RAI Responses.

Response to 9b:

While there would potentially be some benefit in terms of simplification to using the same plant condition requirements for all measurements, the cost of that approach could result in unnecessary delays during power ascension to wait for equilibrium, or reduced accuracy in the monthly $F_Q^W(Z)$ surveillances at 100% RTP, if equilibrium conditions do not exist.

RAI No. 10: Required Actions

Background

In Required Action A (and Required Action B.2) there is a Note that states that Required Action A.4 (Required Action B.2.4) "*shall be* [emphasis added] completed whenever the Condition is entered." However, the completion time for Required Action A.4 (or B.2.4) is "prior to increasing THERMAL POWER above the limit of Required Action A.1 (B.2.1)."

Issue and Request

The Required Actions A.4 and B.2.4 are surveillance requirements. Because of the NOTE accompanying these actions, it is not clear if they must be carried out along with the other Required Actions or whether they can wait until a decision is made to increase THERMAL POWER.

Discuss and clarify the timing of the surveillance to be performed to satisfy both the NOTE and the Required Action B.2.4.

Response to RAI No. 10:

Both Notes, as currently worded, could be interpreted to require that SR 3.2.1.1 and SR 3.2.1.2 be completed upon initial entry into Condition A or performance of Required Action B.2.1. The intent of the Note is that the Surveillances be completed prior to increasing the limitation on THERMAL POWER required by Required Actions A.4 and B.2.4.

Revised Technical Specification markups are included as Attachments 3 and 5 to the RAI responses.

RAI No. 11: Interface of WCAP-17661-P changes with TS 3.2.1A, Heat Flux Hot Channel Factor ($F_Q(Z)$) (CAOC-F_{xy} Methodology)

Background

In addition to TS 3.2.1B and TS 3.2.1C, TS 3.2.1A is included for some CAOC plants. No change is proposed for TS 3.2.1A. It is our understanding that some CAOC plants confirm $F_Q(Z)$ indirectly by measuring F_{xy}^M (Z) and then comparing this measurement to an $F_{xy}(Z)$ limit. In the new formulation, the key factor being measured is also $F_{xy}(Z)$.

Issue and Request

In both TS 3.2.1 A and TS 3.2.1C, the key factor being measured is $F_{xy}(Z)$. However, the TS requirements are different. Some of the concept used in TS 3.2.1C is not used in TS 3.2.1A: namely, TS 3.2.1A is not modified to use a different operating space and avoid reduction in THERMAL POWER.

a. Delineate the difference between CAOC- F_{xy} Methodology and CAOC-T(z) Methodology to explain why the changes similar to that considered for TS 3.2.1C are not applicable for TS 3.2.1A.

b. For CAOC plants, when $F_Q(Z)$ is not within limit, $F_Q^C(Z)$ will also be outside the limit. Under the proposed changes, Required Actions for TS 3.2.1A and TS 3.2.1C are different. Explain and justify the merits of the differences in the TS.

Response to RAI No. 11:

Response to 11a and 11b:

WCAP-17661-P addresses the issue in NSAL-09-5, Revision 1 that was identified with TS 3.2.1B. Improvements are also proposed for TS 3.2.1C in order to add the flexibility of implementing a new CAOC operating space, as opposed to the alternative of reducing THERMAL POWER in the event $F_Q^W(Z)$ exceeds the limit, and to clarify the surveillance requirements, consistent with the proposed changes to TS 3.2.1B. There are no issues associated with TS 3.2.1A in NUREG-1431.

The key parameter being measured in TS 3.2.1C is the steady state $F_Q(Z)$ distribution, not the $F_{XY}(Z)$ distribution. The transient $F_Q^W(Z)$ in TS 3.2.1C is established by multiplying the steady state measured $F_Q(Z)$ distribution by analytically determined surveillance factors, as shown in Equations 7-13 and 7-14 of WCAP-17661-P.

In TS 3.2.1A, only a single LCO is defined as $F_Q(Z)$. TS 3.2.1A does not define measured parameters called $F_Q^C(Z)$ and $F_Q^W(Z)$ to verify this limit. However, the Surveillance Requirements in TS 3.2.1A require periodic surveillances to be performed (measurements) of both the steady state $F_Q(Z)$ distribution (which is analogous to $F_Q^C(Z)$ in TS 3.2.1C), and the $F_{XY}(Z)$ distribution. $F_{XY}(Z)$ is measured by performing SR 3.2.1.2 only for the purpose of confirming that the nuclear design calculations for operational power maneuvers remain bounding. SR 3.2.1.2 in TS 3.2.1A is therefore performed for the purpose of confirming that the analyzed values of the transient $F_Q(Z)$ will remain conservative, and as a result, that the $F_Q(Z)$ will be met during transient operation within the allowed AFD operating space. SR 3.2.1.2 in TS 3.2.1A does not determine a specific measured approximation of the transient $F_Q^W(Z)$.

The Required Actions in TS 3.2.1A are more conservative than those in proposed TS 3.2.1C. This is because TS 3.2.1A effectively treats all cases where the $F_Q(Z)$ limit is exceeded as if the plant is currently operating with a peak power density in excess of that that is assumed in the safety analysis. In a case where SR 3.2.1.1 has shown that the current operating steady state $F_Q(Z)$ has met the limit, and SR 3.2.1.2 has determined that the measured $F_{XY}(Z)$ exceeds the $F_{XY}(Z)$ limit, the Required Actions of TS 3.2.1A Condition A require a reduction in THERMAL POWER with a Completion Time of 15 minutes. An analogous Condition in proposed TS 3.2.1.B or TS 3.2.1.C would allow a new operating space or power reduction to be implemented with a Completion Time of 4 hours.

While it has been identified in Section 10.3 of WCAP-17661-P that the F_{XY} limit in TS 3.2.1A SR 3.2.1.2 is sensitive to differences in the measured and predicted steady state axial power distribution, guidance has been issued by Westinghouse that will ensure that any significant and sustained differences in the measured and predicted steady state axial power distribution are evaluated before the F_Q limit can be challenged. The plants that have implemented TS 3.2.1A do not have to implement proposed TS 3.2.1C, since the resulting surveillances required by TS 3.2.1A are valid and conservative. This paragraph clarifies the discussions of TS 3.2.1A contained in WCAP-17661.

In summary, the changes that are proposed for TS 3.2.1C are not applicable to TS 3.2.1A because the fundamental measured parameters are different (with respect to transient F_Q), and because there are no issues associated with TS 3.2.1A that would result in non-conservative $F_Q(Z)$ measurements or Required Actions in the event that the F_Q limit is not met.

RAI No. 12: Impact of the proposed changes on TS 3.2.4, Quadrant Power Tilt Ratio (QPTR)

Background

TS 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," provides limits and conditions and associated surveillance requirements for QPTR. As stated in the Bases for Section 3.2.4, the QPTR limits ensure that nuclear enthalpy rise hot channel factor ($F^N_{\Delta H}$) and $F_Q(Z)$ remain below their limiting values by preventing an undetected change in the gross radial power distribution. The QPTR limit of 1.02, at which corrective action is required, provides a margin of protection for both the departure from nucleate boiling ratio and linear heat generation rate contributing to excessive power peaks resulting from X-Y plane power tilts. A limiting QPTR of 1.02 can be tolerated before the margin for uncertainty in $F_Q(Z)$ and $F^N_{\Delta H}$ is possibly challenged.

Issue and Request

Under the proposed changes, when a different operating space is implemented, QPTR may be affected. Since QPTR provides a margin of protection, assurance is needed that the margin of protection is not being lost or that adequate margin of protection will still be maintained.

a. Discuss the impact of the proposed changes on the QPTR and how the changes may impact the current LCO and SR in TS 3.2.4.

b. If changes are non-negligible, discuss that adequate margin of protection is being maintained.

Response to RAI No. 12:

Response to 12a:

The implementation of a different operating space in the event that the performance of an $F_Q^W(Z)$ surveillance determines that the F_Q limit is not met would not significantly affect the indicated QPTR on the excore detectors, nor would it affect the actual in-core power distribution symmetry. The primary purpose of implementing a different operating space is to allow the use of smaller surveillance factors T(Z) or W(Z), in order to establish the new $F_Q^W(Z)$ associated with transient operation at the edge of the allowed operating space.

The standard QPTR limit of 1.02 was established with the intention of indicating that a detectable change has occurred in the core power distribution symmetry, and to initiate the performance of SR 3.2.1.1, SR 3.2.1.2, and SR 3.2.2.1 using the movable incore detector system to determine the actual margin to safety analysis limits. QPTR indicates only a gross change in the average power of each core quadrant. The TS 3.2.4 Required Action A.1 to reduce THERMAL POWER by $\geq$ 3% from RTP for each 1% of QPTR > 1.00 is precautionary, until such time as the actual margin to the safety analysis limits can be re-assessed and confirmed using the movable incore detector system. As required by Required Action A.5 of TS 3.2.4, once the incore detector surveillances are completed and the safety analysis is re-evaluated, the excore detectors will be normalized to restore the QPTR to within the limit. Once the THERMAL POWER is restored to 100% RTP, SR 3.2.1.1, SR 3.2.1.2, and SR 3.2.2.1 are performed as required by Required Action A.6, to confirm that the safety analysis limits are still met. No minimum margin requirements are specified for the results of SR 3.2.1.1, SR 3.2.1.2, and SR 3.2.2.1, which are required by TS 3.2.4 Condition A, other than that the safety analysis limits must be met using the normal measurement and fuel manufacturing tolerance uncertainties implemented by the plant.

Response to 12b:

In the response to RAI No. 5, it was identified that performing SR 3.2.1.1 and SR 3.2.1.2 will be added as Required Actions with a 72 hour Completion Time, if a new operating space is implemented if $F_Q^W(Z)$ exceeds the F_Q limit, and control rod motion is required to comply with the new operating space. By adding this Required Action, the margin to safety analysis limits will be determined and confirmed after the implementation of a new operating space, including the effects of any existing QPTR. Once this is done, the same initial conditions are established with respect to the continued applicability of TS 3.2.4, as would otherwise have been present before the new operating space was implemented. Therefore, TS 3.2.4 will continue to provide the requisite margin of protection.

RAI No. 13: Additional discussion of methodology

Background

The RAOC-T(Z) methodology is presented in different sections in WCAP-17661-P for the reader to understand the methodological issues. Details and example results are given; however, some aspects of the discussion of the methodology to obtain $F_Q^W(Z)$ can be considered lacking.

Issue and Request

Additional discussion on the following aspects is requested in order to fully understand the methodology:

a. Provide the specific assumptions, limitations, implementing procedures, and related guidance associated with the methodology and explain how they have been addressed in defining the new requirements.

b. Discuss the attributes/results of the methodology and relate them to the changes proposed in the Specifications. Discuss each of the changes in the Specifications and their relation to the improved methodology if one exists.

c. Discuss any differences from the results presented for a Westinghouse 4-loop plant that might be expected for different designs.

Response to RAI No. 13:

Response to 13a:

The discussion of the methodology to obtain predicted $F_Q^W(Z)$ was not included because these methods have not changed from previous NRC approved methods. The RAOC analysis methods are the same, except for the concept of potentially analyzing multiple operating spaces for a given unit/cycle, instead of just one operating space. The RAOC analysis methods are defined and approved by the NRC in Part A of WCAP-10216-P-A (which is reference 5 in WCAP-17661-P). The information contained in Part B of WCAP-10216-P-A, which describes the original implementation of the F_Q Surveillance Technical Specification, will be superseded by the Improved F_Q Surveillance Technical Specifications contained in WCAP-17661-P. CAOC analysis methods are defined and approved by the NRC in WCAP-8385, NS-CE-687, and NS-TMA-2198 (which are references 2, 3, and 4 in WCAP-17661-P). WCAP-8385 was approved by the NRC in a letter from J. F. Stolz (NRC) to C. Eicheldinger (Westinghouse), "Safety Evaluation of WCAP-8385 (P) and WCAP-8403 (NP)," dated January 31, 1978. The specific calculations to obtain the peak predicted transient F_Q will continue to be performed using either the 2D/1D synthesis methods (originally approved by the NRC in WCAP-8385 Section 5, and summarized succinctly by Equation 2-10 of WCAP-17661-P), or by using an NRC approved 3D computer code, such as the Westinghouse ANC code (WCAP-10965-P-A). The application of calculational uncertainties is not changing as a result of the development of WCAP-17661-P (see the response to RAI No. 4 for a discussion of the calculational uncertainties). There are no specific assumptions or limitations in the original approved analysis methods that are adversely affected by the changes to the Improved F_Q Surveillance Technical Specifications proposed in WCAP-17661-P.

While specific revisions to the implementing nuclear design procedures have not been completed at this time, there have been sample calculations performed in support of the data contained in WCAP-17661-P. These sample calculations will form the basis for revising the nuclear design procedures to implement the new methodology at Westinghouse.

In the sample calculations discussed above, the predicted transient $F_Q^W(Z)$ power shapes were generated for a sample 4-loop plant using the standard RAOC and CAOC analysis procedures, for multiple operating spaces. The analysis of a different operating space is a relatively simple process that involves changing a few input values in the standard computer runs to define the allowed AFD band and rod insertion limits. Similarly, the margin improvements associated with reducing the maximum allowed power level and AFD band for each defined operating space (Tables 6-10 and 9-7 in WCAP-17661-P) were quantified by changing the applicable inputs defining the maximum allowed power level and AFD band, and then running the standard set of cases, as if it were a new operating space. The automated sequences within the computer codes generate standard transient simulations which operate within the allowed operating space provided in the inputs. The number of specific operating spaces and margin improvement calculations that will be analyzed in advance for any given plant will depend on the plant specific needs.

The calculation of the new surveillance parameters in support of the Improved F_Q Technical Specifications [i.e., T(Z), $A_{XY}(Z)$, $A_Q(Z)$, and the Rj factor] will be performed in accordance with the respective equations used to define these parameters in WCAP-17661-P (i.e., Equations 4-30, 4-35, 7-10, and 5-9 in WCAP-17661-P, respectively). T(Z) may alternatively be determined

from currently calculated values of W(Z) using Equation 4-33 in WCAP-17661-P, but this will result in the same T(Z) values as would be obtained from Equation 4-30. The values necessary to calculate these parameters are already determined as part of the RAOC or CAOC analysis.

In the case of $A_{XY}(Z)$ and $A_Q(Z)$, most surveillances will be performed using values of unity, at least for surveillances performed at 100% RTP with all rods out. Specific $A_{XY}(Z)$ and $A_Q(Z)$ values may be provided in the plant COLRs for surveillances that are performed during the initial power ascension following a refueling, as requested by the plant. An option may be implemented in the Westinghouse BEACON Core Monitoring System (WCAP-12472-P-A) to automatically generate $A_{XY}(Z)$ and $A_Q(Z)$ values specific to the conditions where the surveillance is performed using the methods discussed in Sections 4.3.2 and 7.3.2 of WCAP-17661, respectively. The BEACON Core Monitoring System is currently used to perform the F_Q surveillances in many Westinghouse NSSS plants.

As discussed in the Safety Evaluations/Final Safety Evaluations for WCAP-12472-P-A and Addendums 1 through 4, the BEACON™ Core Monitoring System is a core monitoring and support package that uses core power distribution and plant process instrumentation in conjunction with this NRC approved analytical methodology for online generation of calibrated 3-dimensional core power distributions. The BEACON™ system is approved by the NRC for core monitoring activities, including the determination of the measured transient $F_Q^W(Z)$ which is required by SR 3.2.1.2.

The analytical methodologies that are implemented in the BEACON™ system are the same NRC approved methodologies that are implemented in the Westinghouse ANC code (WCAP-10965-P-A Revision 0 through Addendum 2A), which can also be used to calculate the $A_{XY}(Z)$ and $A_Q(Z)$ values contained in the COLR. The determination of the $A_{XY}(Z)$ and $A_Q(Z)$ values by the BEACON™ system can be done in one of two ways as discussed below.

- Since the BEACON™ system is provided with the current plant conditions where the surveillance is performed, and the conditions that were assumed in generating the reference T(Z) or W(Z) surveillance factors. The determination of the $A_{XY}(Z)$ and $A_Q(Z)$ values at the conditions where the surveillance is performed, can be done by calculating two different 3-D power distributions in BEACON™ and solving either Equation 4-35 in WCAP-17661-P for $A_{XY}(Z)$ or Equation 7-10 in WCAP-17661-P for $A_Q(Z)$.

- The reference $F_{XY}(Z)$ and $F_Q(Z)$ functions that are consistent with the T(Z) or W(Z) surveillance factors can be input to the BEACON™ core model. Then the determination of the $A_{XY}(Z)$ and $A_Q(Z)$ values at the conditions where the surveillance is performed, can be done by calculating the 3-D power distribution in BEACON™ at the surveillance conditions and solving either Equation 4-35 in WCAP-17661-P for $A_{XY}(Z)$ or Equation 7-10 in WCAP-17661-P for $A_Q(Z)$.

With either approach the, the determination of the $A_{XY}(Z)$ and $A_Q(Z)$ values at the conditions where the surveillance is performed using the BEACON™ system will be consistent with the current NRC approved methodology for determining 3-D power distributions in WCAP-12472-P-

A and Addendums 1 through 4, and the updated F_Q surveillance methodologies that will be approved in WCAP-17661-P.

The Rj factor is currently already calculated by Westinghouse in support of the current F_Q Technical Specification Surveillance methodology, as shown in Equation 5-9 of WCAP-17661-P. Rj quantifies the maximum *predicted* decrease in the transient $F_Q^W(Z)$ margin over the next period of operation prior to the next performance of SR 3.2.1.2, from any point forward in the cycle. In the revised F_Q surveillance methodology contained in WCAP-17661, no minimum value will be imposed on the value of Rj, except that Rj will never be specified as being less than 1.0, even if it is predicted that the transient $F_Q^W(Z)$ margin will increase during the next Frequency when SR 3.2.1.2 is performed. The actual calculated Rj penalty will be applied to all $F_Q^W(Z)$ surveillances, instead of focusing the application of the penalty during the performance of any individual surveillance on an observed decrease in $F_Q^C(Z)$ margin from the previous performance of SR 3.2.1.2.

As discussed at the bottom of page 5-8 of WCAP-17661-P, the Rj factors are calculated in accordance with the Surveillance Frequency applied in SR 3.2.1.2. The proposed versions of SR 3.2.1.2 in WCAP-17661-P TS 3.2.1B and TS 3.2.1C have been developed with the recognition that some plants may have the SR 3.2.1.2 Frequency in a Surveillance Frequency Control Program. It is also possible that some plants may elect to perform SR 3.2.1.2 more frequently than required, during times in the cycle when the $F_Q^W(Z)$ margin is limited, or for other reasons. As a minimum, the Rj penalty factor function provided in the COLR will support the SR 3.2.1.2 required Frequency. If a plant elects to perform SR 3.2.1.2 more frequently than required, either for all or part of a cycle, an appropriate Rj penalty factor may optionally be developed to support that Frequency, and would also be provided in the COLR. For example, if a plant notifies Westinghouse that it intends to perform SR 3.2.1.2 on an optional 7 EFPD Frequency during parts of the cycle, an Rj function applicable to the 7 EFPD Frequency may be provided in the COLR in addition to the standard 31 EFPD Rj penalty. The Rj penalty for the optional 7 EFPD Frequency would be calculated in the same manner as the 31 EFPD Rj penalty, except that it would be based on the maximum predicted decrease in transient $F_Q^W(Z)$ margin for the next 7 EFPDs of operation (instead of the next 31 EFPDs). While performing the Surveillance on a 7 EFPD Frequency, the 7 EFPD Rj function would be used by the plant. If the plant decides to revert back to the required 31 EFPD Frequency for SR 3.2.1.2, the 31 EFPD Rj function would be used for the first Surveillance performed prior to increasing the Frequency back to 31 EFPDs (i.e., based on the planned time interval before the next performance of SR 3.2.1.2).

The following is the specific justification for basing the calculated Rj factor on only the *predicted* trend in the future transient $F_Q^W(Z)$ margin, and not including the effect of measurements from past operation or additional uncertainty.

The purpose of the Rj factor is to ensure that the $F_Q^W(Z)$ limit will not be exceeded prior to the performance of the next $F_Q^W(Z)$ surveillance. Rj is not used in the plant safety analysis. The measured trend in the transient $F_Q^W(Z)$ margin is significantly affected by the burnup dependent behavior of the predicted surveillance factors T(Z) and W(Z). In other words, the predicted T(Z) and W(Z) surveillance factors affect both the predictions and measurements of the transient $F_Q^W(Z)$ margin by the same amount. Only the radial component of the measured power distribution ($F_{XY}(Z)$) affects the transient $F_Q^W(Z)$ margin for RAOC plants. This steady state radial component varies much more slowly with burnup than the $F_Q^W(Z)$ value, which is affected by

both radial and axial trends.

As discussed in the response to RAI No. 6, it has been shown that trends in $F_Q^C(Z)$ margin do not always correlate with trends in the $F_Q^W(Z)$ margin, because of the effect of the surveillance factor variations with burnup. Furthermore, the observed trend in $F_Q^C(Z)$ margin for the *past* 31 EFPDs of operation may not be indicative of the expected decrease or increase in $F_Q^W(Z)$ margin over the *next* 31 EFPDs of operation. The $F_Q^C(Z)$ margin may increase during one 31 EFPD period and then decrease during the next 31 EFPD period, and it may even oscillate in both directions over several 31 EFPD surveillances. These increases and decreases in observed $F_Q^C(Z)$ margin may be real (due to fuel depletion effects), however they may also be due to the random uncertainties associated with all power distribution measurements. They could also be due to minor operational differences, such as operating at a few percent different AFD (within the allowed AFD band) between 31 EFPD power distribution surveillances.

See the response to RAI 4b, regarding the uncertainties for the T(Z) surveillance factors.

In the event there is some unpredicted, but real anomaly occurring in the core, which results in the $F_Q^W(Z)$ margin decreasing faster than predicted, the anomaly will most likely develop slowly and be observable over several power distribution measurements before the F_Q limit is actually challenged (e.g., CIPS). Guidance has been issued by Westinghouse for identifying slowly developing radial and axial power anomalies such as CIPS, and evaluating the effect of their occurrence before the F_Q limit is challenged. Quadrant Power Tilt Ratio (QPTR) monitoring will ensure that any more rapidly developing disturbances in the radial power distribution are identified between 31 EFPD surveillances, and the Required Actions for exceeding the QPTR limit require that the $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances be performed to determine the current operating margin. Finally, it should be noted that the calculations performed to develop the predicted Rj penalties are conservative, because they base the penalty for the next 31 EFPD of operation on the most conservative result obtained from 1/8 month interval segments in the next 31 EFPDs (see equation 5-9 in WCAP-17661-P).

Response to 13b:

The key attributes/improvements of the revised F_Q Technical Specification Surveillance methodology can be summarized as follows, and related to the specific changes in the Technical Specifications 3.2.1B and 3.2.1C:

1) The formulation for determining the measured transient $F_Q^W(Z)$ in RAOC plants has been revised to be less sensitive to the ability to predict the actual steady state axial power shape conditions where the surveillances are performed.

   This is related to the use of the new T(Z) surveillance factor, which no longer includes the steady state axial power shape in the denominator, relative to the original W(Z) factor.

2) Correction factors have been defined for the new F_Q surveillance equations which correct the results for any remaining errors associated with the actual plant conditions where the surveillance is performed, which may differ from the predicted surveillance condition. These factors are the $A_{XY}(Z)$ factors for RAOC plants and the $A_Q(Z)$ factors for CAOC plants, which have been added to the respective equations used to perform the

$F_Q{}^W(Z)$ surveillance (see equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P). Multiple methods have been presented for representing the $A_{XY}(Z)$ and $A_Q(Z)$ factors. This includes the very simple assumption of unity for the factors, all the way up to rigorous calculation of the factors at the specific conditions of each surveillance.

3) The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillances at part power conditions. This is done by moving the relative power term of the condition where the surveillance is performed out of the surveillance factors (i.e., T(Z) and W(Z)) and into the actual surveillance equations (see equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P). For power levels less than 50% RTP, the F_Q limits are correctly evaluated at the 50% RTP power level.

4) Required Actions for cases where $F_Q{}^W(Z)$ exceeds the F_Q limit have been more rigorously defined, and eliminate all reliance on "rules of thumb" that may not be strictly applicable in all situations. This is implemented through the possible application of new RAOC or CAOC operating spaces, or through the pre-defined limitations on power and AFD provided in the COLR, which are rigorously calculated using the standard NRC approved analysis methods. These changes ensure that corrective actions taken in the rare circumstances when $F_Q{}^W(Z)$ exceeds the F_Q limit will be effective at restoring the necessary margin.

5) The application of the burnup dependent penalty factor (Rj) to account for predicted decreases in the transient $F_Q{}^W(Z)$ margin during the next 31 EFPDs has been modified to apply to all surveillances, independent of the trends in measured $F_Q{}^C(Z)$ margin. This is implemented by incorporating Rj into the surveillance equations (see equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P) and eliminating the conditional application of the penalty factor in the Technical Specification surveillances. This improvement corrects cases where the measured trend in $F_Q{}^C(Z)$ margin from the previous 31 EFPDs may be increasing, but the trend in $F_Q{}^W(Z)$ margin is decreasing due to changes in the surveillance factor data.

6) Requirements to perform SR 3.2.1.1 and 3.2.1.2 have been clarified in cases where $F_Q{}^C(Z)$ and $F_Q{}^W(Z)$ exceed the F_Q limit. In any case where one or both parameters exceed the limit, both surveillances are required to be performed by the Technical Specifications Required Actions.

7) The F_Q surveillance Technical Specifications have been revised to rely on $F_Q{}^C(Z)$ surveillances during the initial power ascension after a refueling to demonstrate that continued power ascension is justified. The first $F_Q{}^W(Z)$ surveillance is not specifically required to be performed until 24 hours after the plant reaches equilibrium conditions at a power level greater than 75% RTP. This change recognizes the technical fact that the surveillance factors needed to perform an accurate $F_Q{}^W(Z)$ surveillance at a very low THERMAL POWER levels are difficult to accurately calculate in advance of the surveillance, and that the most accurate $F_Q{}^W(Z)$ surveillances will be obtained from equilibrium conditions at greater than 75% RTP. The change is justified by the fact that the $F_Q{}^C(Z)$ surveillances confirm the core is behaving as predicted, and the initial power ascension after a refueling outage is performed in a slow, controlled manner, until the fuel is conditioned. The first $F_Q{}^W(Z)$ surveillance that is performed following a refueling justifies operation at 100% RTP over the next 31 EFPDs, under potential transient

operation.

In summary, a number of improvements have been made to the F_Q Technical Specification surveillance methodology for RAOC and CAOC plants, which improve the expected accuracy of the surveillances, and which provide Required Actions that are demonstrated to be effective at restoring the required margin in the event the F_Q limit is exceeded.

Response to 13c:

The choice of a 4-loop Westinghouse plant for performing the demonstration calculations supporting the results shown in WCAP-17661-P does not affect any of the methods or justifications discussed in WCAP-17661-P. Standard RAOC and CAOC calculations are routinely performed for all types of Westinghouse NSSS plants, and for other types of PWRs which are licensed using the Westinghouse safety analysis methodology. In generating a COLR for a different type of plant, or even for a 4-loop plant with a different fuel type or $F^N_{\Delta H}$ limit, it would be expected that the rod insertion limits and allowed AFD operating bands could be significantly different than those presented in WCAP-17661-P. Also, the margin gains associated with implementing a different operating space, or a power reduction could be different as well. However, all the methods for performing the calculations remain applicable. Actual violations of the F_Q limit are unlikely based on past operating experience, and will continue to be so in the future. However, the implementation of a more rigorous approach to define the Required Actions in the event of an F_Q violation will ensure that this key safety analysis parameter is expeditiously restored to within it limit, if the limit is not met.

RAI No. 14: Adjustment factor for the radial peaking factor ($A_{XY}(z)$)

Background

Appendix C, "Sample COLR Input for a RAOC Plant," indicates in limit C.2.2.6 that "$A_{XY}(z)$ may be assumed equal to 1.0 or may be determined for specific surveillance conditions using the approved methods listed in TS 5.6.5." This follows discussion contained in Sections 4.3 and 6.4 of the main topical report.

Issue and Request

Regarding Method 2 as described in Licensing Topical Report (LTR) Section 4.3:

a. Provide a comprehensive list of all approved methods that may be used to calculate $A_{XY}(z)$, according to Method 2.

b. Since $A_{XY}(z)$ is a factor used to scale a surveillance value that is used to confirm adherence to a cycle-specific parameter operating limit, its reciprocal could, if applied to the operating limit, be considered a cycle (or, more specifically, situation)-specific scaling factor for a parameter operating limit. The core physics methodology, or computer code, used to calculate this value would need to be referenced in the TS COLR References list, for consistency with Generic Letter 1988-16 guidance.

c. Explain whether $A_{XY}(z)$ is calculated on-site by an implementing licensee, or whether Westinghouse or the PWROG, as supporting vendors, calculate these values.

d. Provide the procedures or engineering guidelines for calculating these values for NRC staff review.

Regarding Methods 3 and 4 as described in LTR Section 4.3:

e. Various passages of text in the LTR appear to acknowledge many shortcomings associated with these methods. For example, Page 6-3 states, "Obviously, this method is somewhat awkward given the large number of values that must be pre-calculated and the need to determine appropriate values for intermediate power levels and rod positions." Explain what benefit offering these methods provide to any implementing licensee: why make this option available?

Regarding $A_{XY}(z)$ in general:

f. The text in Section 4.3 suggests that incorporating an $A_{XY}(z)$ term in the surveillance formulation is optional. For example, Page 4-9 states, "... use of these factors should be an option... " Explain how $A_{XY}(z)$ is applied if its value is greater than 1.

g. Section 6.4 described $A_{XY}(z)$ values for initial power ascension. If the $F_Q^W(z)$ surveillance is not intended to be performed until after a period of equilibrium operation after exceeding a threshold power level, explain why the $A_{XY}(z)$ factors are necessary or desired for initial power ascension.

Response to RAI No. 14:

Response to 14a:

If Method 2 is used to calculate $A_{XY}(Z)$ for a RAOC plant, it will be done using Equation 4-35 in WCAP-17661-P, using an NRC approved 3D nuclear code such as the Westinghouse ANC code (WCAP-10965-P-A) or the Westinghouse BEACON Core Monitoring System (WCAP-12472-P-A). Both codes are capable of calculating the F_{XY} values needed to evaluate the $A_{XY}(Z)$ factor, and are approved by the NRC. An ANC calculation would have to be manually performed by a qualified user, who would input the conditions of the surveillance directly to the code. The calculation could be automated in the BEACON Core Monitoring System, as this code is currently used to perform the F_Q surveillance measurements for many Westinghouse NSSS plants, and the specific plant conditions where the surveillance will be performed would be available from the plant computer interface with the BEACON system. The calculation could also be performed using another NRC approved computer code capable of calculating the necessary F_{XY} values to solve Equation 4-35.

Response to 14b:

It is agreed that WCAP-17661-P would need to be added to the plant specific TS list of COLR references as required by NRC GL 88-16. In addition, the topical report describing the calculational methods used for the RAOC or CAOC analysis would be retained, to support the nuclear design analysis methods that will be used (for example, WCAP-10216-P-A, Part A, for a RAOC plant). The approved nuclear codes and core physics methods topicals used for a particular plant are typically referenced in the Nuclear Design section of the plant's updated final safety analysis report, as required by NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition.*

Response to 14c:

Method 2 of performing the $A_{XY}(Z)$ calculations could be performed either by Westinghouse or another qualified supporting vendor responsible for generating the surveillance data, or it could be performed by the implementing licensee. If method 2 is used, the most likely implementation will be for the calculation to be performed by the implementing licensee during the performance of the surveillance, using an NRC approved computer code such as the BEACON Core Monitoring System (WCAP-12472-P-A). The BEACON Core Monitoring System contains the Westinghouse ANC nuclear methods, in a model which is automatically calibrated to match plant measured data during operation of the plant.

Response to 14d:

Specific implementing procedures or engineering guidelines have not been developed yet, since they need to be consistent with the final NRC approval of the methodology contained in WCAP-17661. However, as stated in Section 4.3.2 of WCAP-17661-P, the calculation of the F_{XY} parameters needed to solve Equation 4-35 involves two straightforward core calculations: one at the reference conditions assumed for the COLR T(Z) values (e.g., 100% RTP, all rods out, equilibrium xenon) and one at the actual conditions of the $F_Q^W(Z)$ surveillance, which may be at a reduced power level and have some control bank insertion. The calculation of F_{XY} radial peaking factors has been a standard part of Westinghouse nuclear design methods ever since

synthesis procedures were approved by the NRC in WCAP-8385, "Power Distribution Control and Load Following Procedures."

Response to 14e:

The objective of identifying multiple methods is to provide plants with the maximum flexibility for implementation of the methodology. Method 2 will be very easy to implement once incorporated directly into the BEACON Core Monitoring System. However, Method 1 is acceptable for most $F_Q^W(z)$ surveillances. Methods 3 and 4 are intended for plants that may routinely perform $F_Q^W(z)$ surveillances at conditions significantly different than those assumed in generating the T(Z) surveillance factors, and who do not use the BEACON Core Monitoring System.

However, all of the methods are acceptable and will provide accurate results.

Response to 14f and 14g:

When detailed calculations of $A_{XY}(Z)$ are performed using one of the methods defined in WCAP-17661-P, the function is applied as a direct multiplier to the $F_Q^W(Z)$, as shown in Equations 5-1 and 5-2 of WCAP-17661-P. The value is applied as calculated by the NRC approved nuclear code, irrespective of whether or not the calculated value is greater than, less than, or equal to 1.0. The $A_{XY}(Z)$ factor corrects the analytical T(Z) surveillance factors because the $F_{XY}(Z)$ distribution that is used in the denominator of T(Z) was generated at an assumed condition which is not consistent with the actual conditions where the surveillance is performed. The measured F_{XY} distribution (i.e.,$[F_{XY}(z)]_{Surv}^{M}$) from the movable incore detector system is still incorporated directly into the $F_Q^W(z)$ surveillance result.

The change to the initial performance of SR 3.2.1.2 after a refueling within 24 hours after achieving equilibrium conditions after THERMAL POWER exceeds 75% RTP is necessary so that, future surveillances of $F_Q^W(z)$ will be performed at core conditions that are very close to those used in generating the T(Z) surveillance factors, and there will be no significant error introduced by assuming that $A_{XY}(Z)$ is unity. In this case, it would not be necessary to provide $A_{XY}(Z)$ values in the COLR, or calculate them using Method 2 during the performance of the surveillance.

Attachment 3

Technical Specification 3.2.1B
Heat Flux Hot Channel Factor Markups

3.2 POWER DISTRIBUTION LIMITS

3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-W(Z) Methodology)

LCO 3.2.1B $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered. -------------------------------	A.1 Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	<u>AND</u>	
$F_Q^C(Z)$ not within limit.	A.2 Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>	
	A.3 Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>	
	A.4 Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

ACTIONS (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
B. ------------NOTE------------ Required Action B.4 shall be completed whenever this Condition is entered. -------------------------------- $F_Q^W(Z)$ not within limits.	B.1	Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit.	4 hours
	AND		
	B.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced.	72 hours
	AND		
	B.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced.	72 hours
	AND		
	B.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits
C. Required Action and associated Completion Time not met.	C.1	Be in MODE 2.	6 hours

SURVEILLANCE REQUIREMENTS

-----NOTE-----
During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP AND Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified AND [31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	------------------------------NOTE------------------------------ If measurements indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$: a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has not increased. --	
	Verify $F_Q^W(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP <u>AND</u> 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 <u>AND</u>

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

Attachment 4

Technical Specification Bases 3.2.1B
Heat Flux Hot Channel Factor Markups

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-W(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO(QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents an equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$F_Q(Z) \leq (CFQ / P)\ K(Z)$ for $P > 0.5$

$F_Q(Z) \leq (CFQ / 0.5)\ K(Z)$ for $P \leq 0.5$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized FQ(Z) as a function of core height provided in the COLR, and

P = THERMAL POWER / RTP

BASES

LCO (continued)

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of [2.32], and K(Z) is a function that looks like the one provided in Figure B 3.2.1B-1.

For Relaxed Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

The expression for $F_Q^W(Z)$ is:

$$F_Q^W(Z) = F_Q^C(Z)\, W(Z)$$

where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required and if $F_Q^W(Z)$ cannot be maintained within the LCO limits, reduction of the AFD limits is required. Note that sufficient reduction of the AFD limits will also result in a reduction of the core power.

Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.

INSERT 1

The various factors in this expression are defined below:

$F_{XY}^{M}(z)$ is the measured radial peaking factor at axial location z and is equal to the value of $F_{Q}^{M}(z)/P^{M}(z)$, where $P^{M}(z)$ is the measured core average axial power shape.

$[T(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[T(z)]^{COLR}$ functions are specified for each analyzed RAOC operating space (i.e., each unique combination of AFD limits and Control Bank Insertion Limits). The $[T(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each RAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[T(z)]^{COLR}$. The $[T(z)]^{COLR}$ functions also account for the following effects: (1) the presence of spacer grids in the fuel assembly, (2) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (3) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (4) the increase in radial peaking due to non-equilibrium xenon effects. The $[T(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at nominal RTP conditions with all shutdown and control rods fully withdrawn, i.e., all rods out (ARO). Surveillance specific $[T(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

$A_{XY}(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_{XY}^{M}(z)$ to the reference core conditions assumed in generating the $[T(z)]^{COLR}$ factors. Normally, this reference core condition is HFP, ARO, EQXE. For simplicity, $A_{XY}(z)$ may be assumed to be 1.0. If, however, margin is needed for a Surveillance performed at conditions different from the reference core conditions, then the appropriate values for $A_{XY}(z)$ may be used. Sub-factors of $A_{XY}(z)$ may also be determined and included in the COLR. These sub-factors are $F_{PC}(z)$ and $F_{RC}(z)$. $F_{PC}(z)$ is a factor that adjusts the measured $F_{XY}^{M}(z)$ to the reference core power (typically RTP) if the Surveillance is performed at part power conditions. $F_{RC}(z)$ is a factor that adjusts the measured $F_{XY}^{M}(z)$ values to the reference rodded condition (typically ARO) if the surveillance condition includes insertion of the lead control bank. When these sub-factors are used, $A_{XY}(z)$ is the product of $F_{PC}(z)$ and $F_{RC}(z)$.

[1.0815] is a factor that accounts for fuel manufacturing tolerances and measurement uncertainty.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_{Q}^{W}(z)$ between Surveillances. Rj values are provided for each RAOC operating space.

--REVIEWER'S NOTE--
WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux - High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux - High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux - High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux - High trip setpoints.

BASES

ACTIONS (continued)

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1, ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

B.1

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. Reducing the AFD by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, restricts the axial flux distribution such that even if a transient occurred, core peaking factors are not exceeded.

BASES

ACTIONS (continued)

The implicit assumption is that if W(Z) values were recalculated (consistent with the reduced AFD limits), then $F_Q^C(Z)$ times the recalculated W(Z) values would meet the $F_Q(Z)$ limit. Note that complying with this action (of reducing AFD limits) may also result in a power reduction. Hence the need for Required Actions B.2, B.3 and B.4.

B.2

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% by which the maximum allowable power is reduced, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER as a result of reducing AFD limits in accordance with Required Action B.1.

B.3

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% by which the maximum allowable power is reduced, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER as a result of reducing AFD limits in accordance with Required Action B.1.

B.4

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the maximum allowable power limit imposed by Required Action B.1 ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

INSERT 2

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new RAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new RAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new RAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(Z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limit, then Required Action B.2.1 must be entered and THERMAL POWER must be limited to less than or equal to 50% RTP and AFD limits must be reduced by the amounts specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

The Completion Time of 4 hours provides an acceptable time to reduce the THERMAL POWER and AFD limits in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(Z)$ and would require power reductions within 4 hours of the $F_Q^W(Z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(Z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

BASES

ACTIONS (continued)

C.1

If Required Actions A.1 through A.4 or B.1 through B.4 are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.

If THERMAL POWER has been increased by ≥ 10% RTP since the last determination of $F_Q^C(Z)$, another evaluation of this factor is required [12] hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

----------------------------------REVIEWER'S NOTE----------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called W(Z). Multiplying the measured total peaking factor, $F_Q^C(Z)$, by W(Z) gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

The W(Z) curve is provided in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for the following axial core regions, measured in percent of core height:

a. Lower core region, from 0 to 15% inclusive and

b. Upper core region, from 85 to 100% inclusive.

The top and bottom 15% of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.

If the two most recent $F_Q(Z)$ evaluations show an increase in the expression maximum over z [$F_Q^C(Z)$ / K(Z)], it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)

INSERT 3

The measured $F_Q(z)$ can be determined through a synthesis of the measured planar radial peaking factors, $F_{XY}{}^M(z)$, and the measured core average axial power shape, $P^M(z)$. Thus, $F_Q{}^C(z)$ is given by the following expression:

$$F_Q{}^C(z) = F_{XY}{}^M(z)\ P^M(z)\ [1.0815] = F_Q{}^M(z)\ [1.0815]$$

For RAOC operation, the analytical $[T(z)]^{COLR}$ functions, specified in the COLR for each RAOC operating space, are used together with the measured $F_{XY}(z)$ values to estimate $F_Q(z)$ for non-equilibrium operation within the RAOC operating space. When the $F_{XY}(z)$ values are measured at HFP ARO conditions ($A_{XY}(z)$ equals 1.0), $F_Q{}^W(z)$ is given by the following expression:

$$F_Q{}^W(z) = F_{XY}{}^M(z)\ [T(z)]^{COLR}\ Rj\ [1.0815]$$

Non-equilibrium operation can result in significant changes to the axial power shape. To a lesser extent, non-equilibrium operation can increase the radial peaking factors, $F_{XY}(z)$, through control rod insertion and through reduced Doppler and moderator feedback at part-power conditions.

The $[T(z)]^{COLR}$ functions quantify these effects for the range of power shapes, control rod insertion, and power levels characteristic of the operating space. Multiplying $[T(z)]^{COLR}$ by the measured full power, unrodded $F_{XY}{}^M(z)$ value, and the factor that accounts for manufacturing and measurement uncertainties gives $F_Q{}^W(z)$, the maximum total peaking factor postulated for non-equilibrium RAOC operation.

BASES

SURVEILLANCE REQUIREMENTS (continued)

-----------------------------------REVIEWER'S NOTE-----------------------------------
WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification," February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.
----

or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.

Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.

$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.

[The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

-----------------------------------REVIEWER'S NOTE-----------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
---]

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after achieving equilibrium conditions after exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. Also, initial startups following a refueling are slow and well controlled due to startup ramp rate limitations and fuel conditioning requirements. Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit. This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged by non-equilibrium operation.

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented.

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.

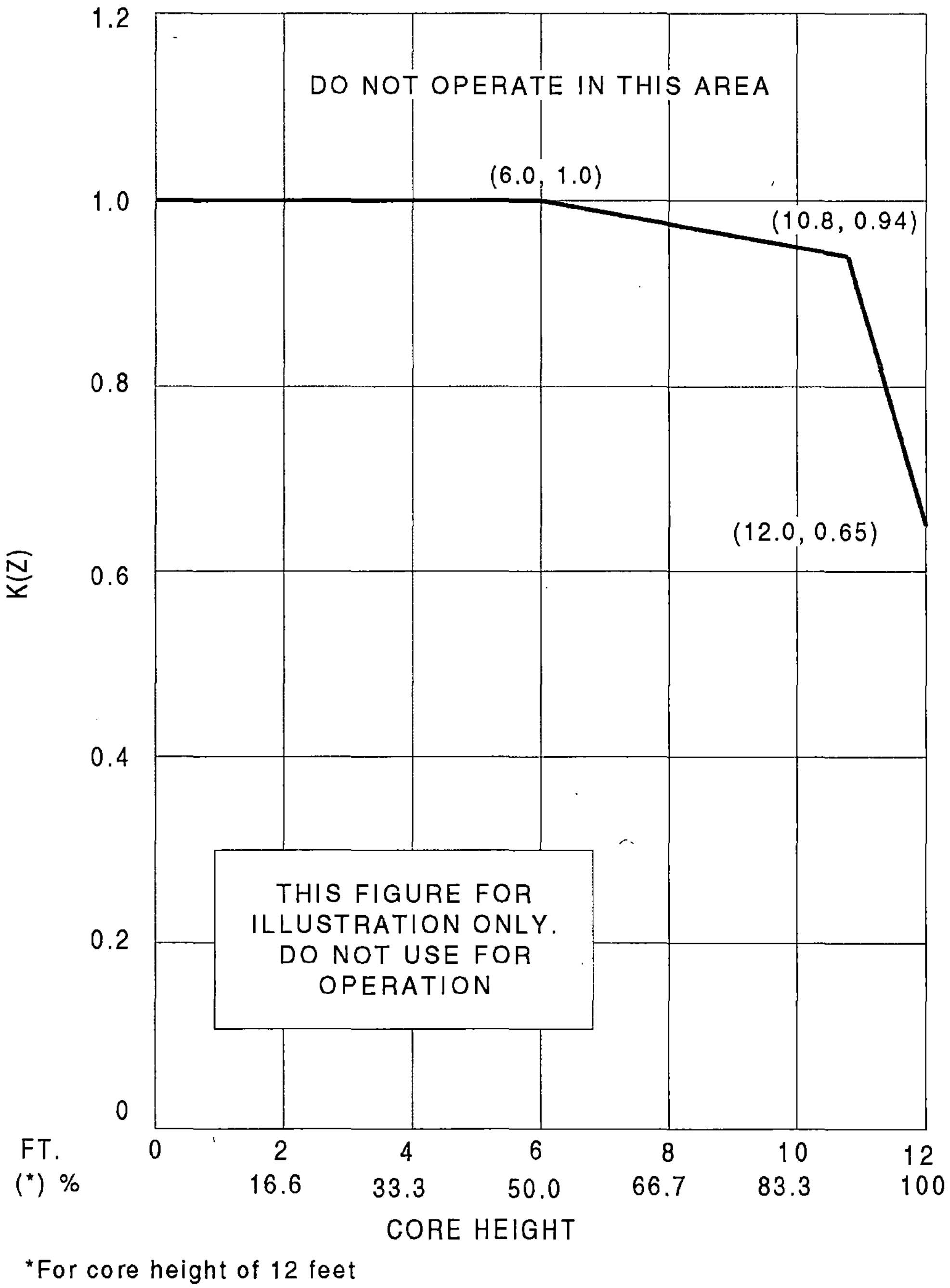
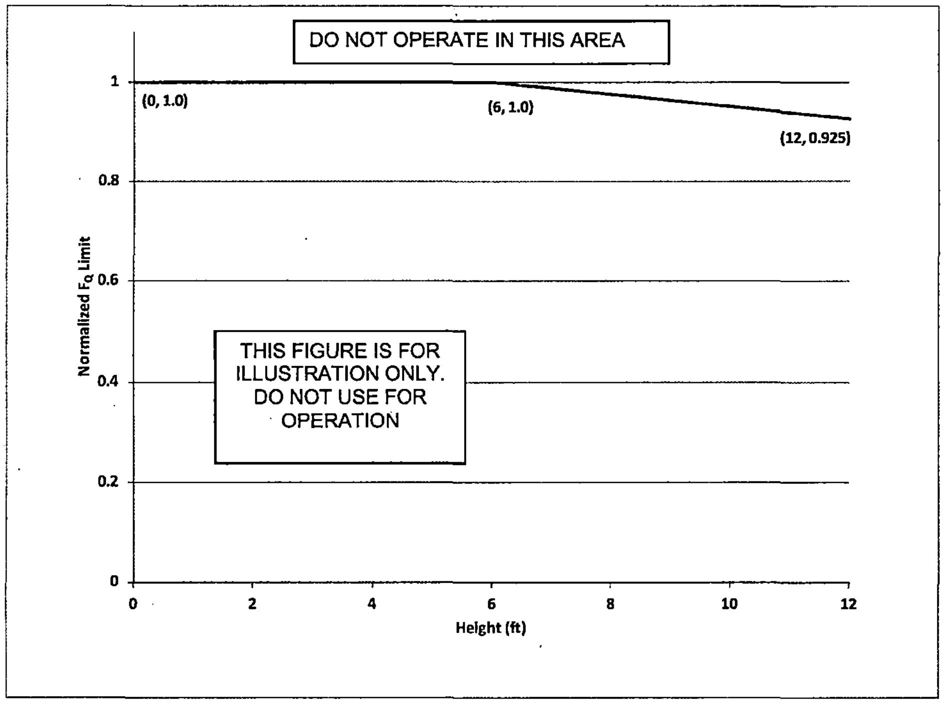


Figure B 3.2.1B-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
1
(0, 1.0)
(6, 1.0)
(12, 0.925)
0.8
0.6
0.4
0.2
0
Normalized F_Q Limit
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION
0
2
4
6
8
10
12
Height (ft)

Attachment 5

Technical Specification 3.2.1C
Heat Flux Hot Channel Factor Markups

3.2 POWER DISTRIBUTION LIMITS

3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

LCO 3.2.1C $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered. --------------------------------	A.1	Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	AND		
$F_Q^C(Z)$ not within limit.	A.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	AND		
	A.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	AND		
	A.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

ACTIONS (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
B. ------------NOTE------------ Required Action B.4 shall be completed whenever this Condition is entered. --------------------------------	B.1	Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit.	4 hours
	AND		
$F_Q^W(Z)$ not within limits.	B.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit.	72 hours
	AND		
	B.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit.	72 hours
	AND		
	B.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action B.1
C. Required Action and associated Completion Time not met.	C.1	Be in MODE 2.	6 hours

SURVEILLANCE REQUIREMENTS

-----NOTE-----

During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP AND Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified AND [31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	------------------------------NOTE------------------------------ If measurements indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$: a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has not increased. ---	
	Verify $F_Q^W(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP <u>AND</u> 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 <u>AND</u>

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

Attachment 6

Technical Specification Bases 3.2.1C
Heat Flux Hot Channel Factor Markups

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO (QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents a equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents.

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$$F_Q(Z) \leq (\ CFQ/P\ )\ K(Z) \qquad \text{for } P > 0.5$$

$$F_Q(Z) \leq (\ CFQ/0.5\ )\ K(Z) \qquad \text{for } P \leq 0.5$$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized $F_Q(Z)$ as a function of core height provided in the COLR, and

P = THERMAL POWER/RTP

BASES

LCO (continued)

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of [2.32], and K(Z) is a function that looks like the one provided in Figure B 3.2.1C-1.

For Constant Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

The expression for $F_Q^W(Z)$ is:

$$F_Q^W(Z) = F_Q^C(Z)\ W(Z)$$

where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required.

Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.

INSERT 1

$[W(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[W(z)]^{COLR}$ functions are specified for each analyzed CAOC operating space (i.e., each unique combination of AFD band and Control Bank Insertion Limits). The $[W(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each CAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[W(z)]^{COLR}$. The $[W(z)]^{COLR}$ functions also account for the following effects: (1) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (2) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (3) the increase in radial peaking due to non-equilibrium xenon effects. The $[W(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at the Target Axial Offset core conditions. Surveillance specific $[W(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

$A_Q(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_Q^M(z)$ to the Target Axial Offset core conditions. For simplicity, $A_Q(z)$ may be assumed to be 1.0 when the surveillance is performed at the target AO. If, however, margin is needed for a Surveillance performed at conditions different from the Target AO core conditions, then the appropriate values for $A_Q(z)$ may be used.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each CAOC operating space.

--REVIEWER'S NOTE--
WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux – High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux – High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux – High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux – High trip setpoints.

BASES

ACTIONS (continued)

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1, ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

B.1

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational

BASES

ACTIONS (continued)

transient occurs. Reducing the THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, maintains an acceptable absolute power density such that even if a transient occurred, core peaking factors are not exceeded.

B.2

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action B.1.

B.3

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action B.1.

B.4

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action B.1 ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

INSERT 2

Implementing a more restrictive CAOC operating space, specified in the COLR, within the allowed Completion Time of 4 hours will restrict the AFD such that core peaking factor limits will not be exceeded during non-equilibrium normal operation. Several CAOC operating spaces, representing successively smaller AFD bands and, optionally, shallower Control Bank Insertion Limits, may be specified in the COLR. The corresponding $[W(z)]^{COLR}$ functions for these operating spaces can be used to determine which CAOC operating space would result in acceptable non-equilibrium operation within the $FQ^{W}(z)$ limit.

INSERT 3

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new CAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new CAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new CAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. If the more restrictive CAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(z)$ limit, the THERMAL POWER must be limited to less than or equal to 50% RTP. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

INSERT 3 (continued)

The Completion Time of 4 hours provides an acceptable time to reduce power in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(z)$ and would require power reductions within 4 hours of the $F_Q^W(z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

BASES

ACTIONS (continued)

C.1

If Required Actions A.1 through A.4 or B.1 through B.4 are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.

If THERMAL POWER has been increased by ≥ 10% RTP since the last determination of $F_Q^C(Z)$, another evaluation of this factor is required [12] hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

---------------------------------REVIEWER'S NOTE---------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called W(Z). Multiplying the measured total peaking factor, $F_Q^C(Z)$, by W(Z) gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

The W(Z) curve is provided in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for the following axial core regions, measured in percent of core height:

a. Lower core region, from 0 to 15% inclusive and

b. Upper core region, from 85 to 100% inclusive.

The top and bottom 15% of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.

If the two most recent $F_Q(Z)$ evaluations show an increase in the expression

maximum over z $[F_Q^C(Z) / K(Z)]$,

it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)

BASES

SURVEILLANCE REQUIREMENTS (continued)

--------------------------------REVIEWER'S NOTE--------------------------------
WCAP-10216-P-A, Rev. 1A, Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification, February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.
----

or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.

Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.

$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.

[The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

--------------------------------REVIEWER'S NOTE--------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
---]

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after achieving equilibrium conditions after exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. Also, initial startups following a refueling are slow and well controlled due to startup ramp rate limitations and fuel conditioning requirements. Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit. This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged by non-equilibrium operation.

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented.

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.

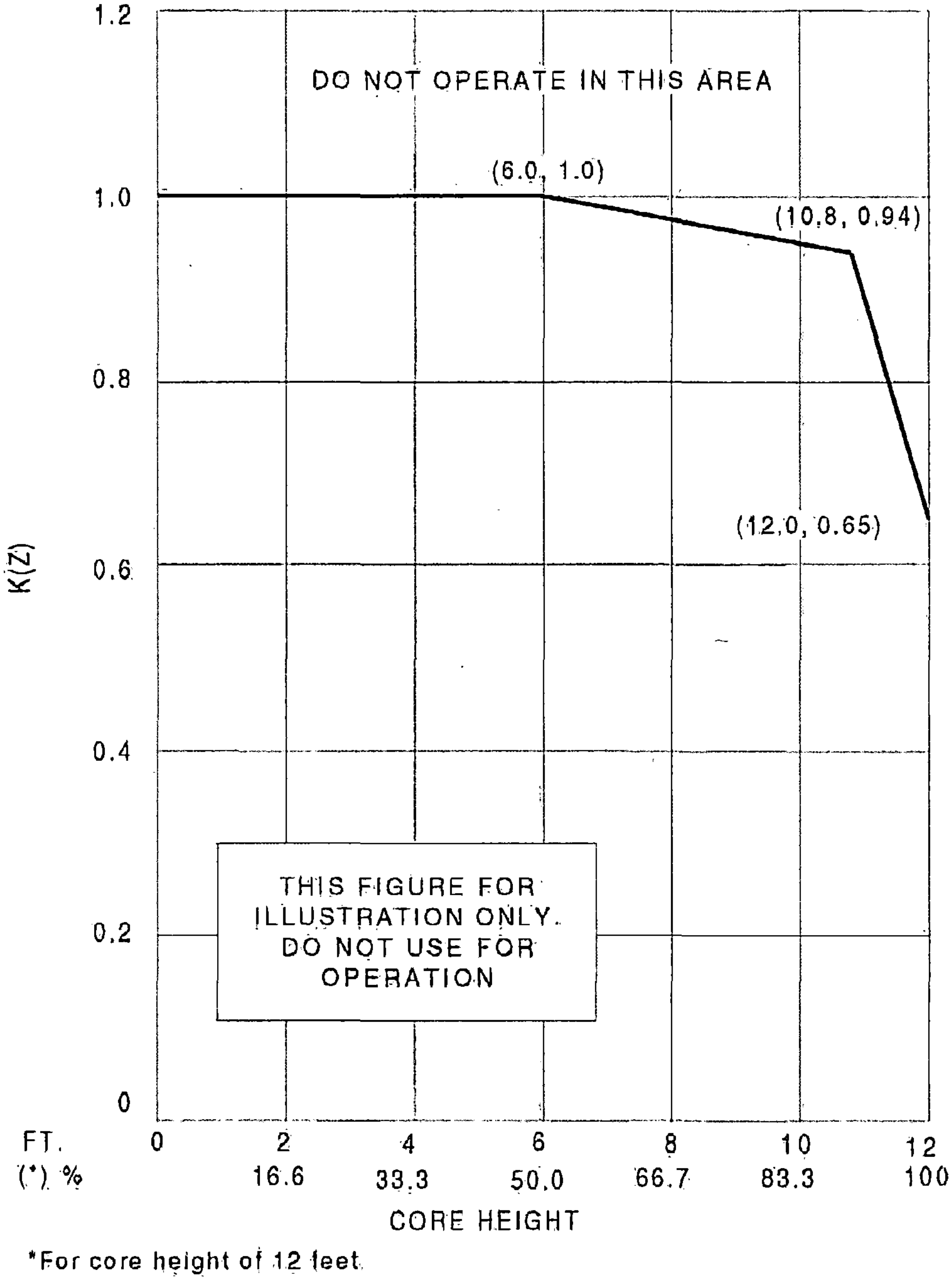
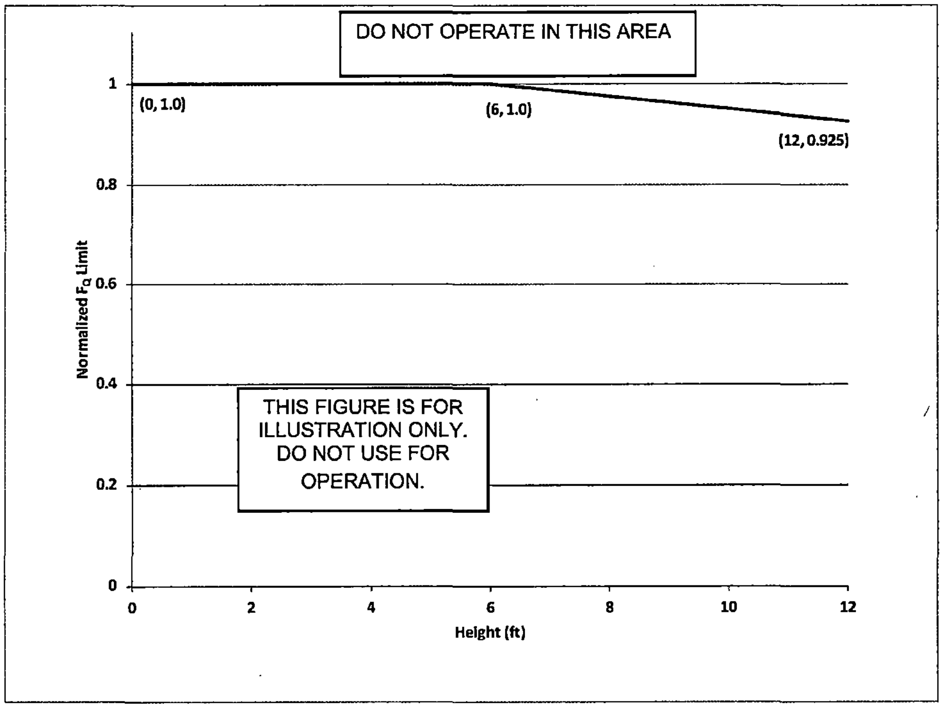


Figure B 3.2.1C-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
(0, 1.0)
(6, 1.0)
(12, 0.925)
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION.
Normalized F_Q Limit
Height (ft)
1
0.8
0.6
0.4
0.2
0
2
4
6
8
10
12

From: Benney, Brian <Brian.Benney@nrc.gov>
Sent: Thursday, July 27, 2017 12:42 PM
To: Holderbaum, Chad M.
Cc: Parks, Benjamin; Andrachek, James D; Florian, Robert J. (SouthernCo); Moorehead, John D.; Hone, Michael J.
Subject: PWROG 17661 RAI for discussion
Attachments: 17661 RAI 15 - proprietary.docx

Chad, here's the RAI for the August 3 phone call. It is encrypted with the same password.
Brian

RAI 15 (Follow-on to RAI 14)

Program Management Office
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

WCAP-17661- P/NP, Revision 1
Project Number 99902037

February 15, 2018

OG-18-35

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Subject: PWR Owners Group
Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795

References:

1. Letter OG-13-427, "Submittal of WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated January 2, 2014

2. NRC Letter of Acceptance for Review of PWROG Topical Report WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 1, 2014

3. NRC Letter for Request for Additional Information RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated December 24, 2014 (TAC NO. MF3348)

4. Letter OG-16-273, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated September 13, 2016

5. Email from the NRC (Benney) to the PWROG (Holderbaum), Request for Additional Information, RAI 15, RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 27, 2017

On January 2, 2014, in accordance with the Nuclear Regulatory Commission (NRC) Topical Report (TR) program for review and acceptance, the Pressurized Water Reactor Owners Group (PWROG) requested formal NRC review and approval of WCAP-17661-P/NP, Revision 1, for referencing in regulatory actions (Reference 1). The NRC Staff has determined that additional information is needed to complete the review per letter dated December 24, 2014 (Reference 3). On September 13, 2016 the PWR Owners Group provided a response the Request for Additional Information (RAI) (Reference 4).

On July 27, 2017, the NRC Staff determined that additional information was needed to complete the review and issued RAI-15 (Reference 5).

The enclosures to this letter provide a response to NRC RAI-15 (Reference 5) associated with WCAP-17661- P/ WCAP-17661-NP, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," Revision 1, and revisions to other documents associated with the response to RAI 15, as identified below.

Enclosed are:

1. LTR-PL&E-18-003, Attachment 1, "RAI-15 Response for WCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Proprietary)
2. LTR-PL&E-18-003, Attachment 2, "RAI-15 Response forWCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Non-Proprietary)
3. LTR-PL&E-18-003, Attachment 3, "Revision to "Insert 1" in the Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273" (Non-Proprietary)
4. LTR-PL&E-18-003, Attachment 4, "Revision to Section F.2.2.6 on Page F-2 of WCAP-17661, Revision 1 (Sample COLR Input for a CAOC Plant)" (Non-Proprietary)

Also enclosed are the Westinghouse Application for Withholding Proprietary Information from Public Disclosure, CAW -18-4708, accompanying Affidavit, Proprietary Information Notice, and Copyright Notice.

As Item 1 contains information proprietary to Westinghouse Electric Company LLC ("Westinghouse"), it is supported by an Affidavit signed by Westinghouse, the owner of the information. The Affidavit sets forth the basis on which the information may be withheld from public disclosure by the Nuclear Regulatory Commission ("Commission") and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the copyright or proprietary aspects of the item listed above or the supporting Westinghouse Affidavit should reference CAW-18-4708 and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2 Suite 259, Cranberry Township, Pennsylvania 16066.

Correspondence related to this transmittal should be addressed to:

Mr. W. Anthony Nowinowski, Executive Director
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

If you have any questions, please do not hesitate to contact me at (805) 545-4328 or Mr. W. Anthony Nowinowski, Program Manager of the PWR Owners Group, Program Management Office at (412) 374-6855.

Sincerely yours,

Ken J Schrader

Ken Schrader, COO & Chairman
PWR Owners Group

JKS:am

cc: PWROG Licensing Subcommittee (Participants of PA-LSC-0795)
PWROG PMO
PWROG Steering and Management Committee
J. Gresham, Westinghouse
J. Andrachek, Westinghouse
J. Moorehead, Westinghouse
M. Hone, Westinghouse
J. Brown, Westinghouse
B. Benney, US NRC

Enclosure 1: LTR-PL&E-18-003, Attachment 1, "RAI-15 Response for WCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Proprietary)

Enclosure 2: LTR-PL&E-18-003, Attachment 2, "RAI-15 Response forWCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Non-Proprietary)

Enclosure 3 LTR-PL&E-18-003, Attachment 3, “Revision to “Insert 1” in the Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273” (Non-Proprietary)

Enclosure 4 LTR-PL&E-18-003, Attachment 4, “Revision to Section F.2.2.6 on Page F-2 of WCAP-17661, Revision 1 (Sample COLR Input for a CAOC Plant)” (Non-Proprietary)

Enclosure 5: Affidavit for Withholding, CAW-18-4708 (Non-Proprietary) with accompanying Affidavit, Proprietary Information Notice and Copyright Notice

Attachment 2

RAI-15 Response for

WCAP-17661-P/ WCAP-17661-NP, Revision 1

(PA-LSC-0795) (Non-Proprietary)

(57 total pages including Attachment 2 cover page and WCAP-17661-NP markup pages)

RAI 15 (Follow-on to RAI 14)

Response to RAI 15.a (Diffusivity of Methods)

It is agreed that Methods 3 and 4, which were proposed to calculate the $A_{XY}(z)$ factors (as discussed in Sections 4.3.3 and 4.3.4 of the TR, respectively) and Method 3, which was proposed to calculate the $A_Q(z)$ factors (as discussed in Section 7.3.3 of the TR) should not be used, and will be deleted from the TR. Attachment 1 (Proprietary) and Attachment 2 (Non-Proprietary) contain the revised pages of the TR that reflect deleting Methods 3 and 4. The deletion of Methods 3 and 4 required revising the discussion of how the $A_{XY}(z)$ and $A_Q(z)$ factors are applied when the $F_Q^W(z)$ Surveillance is performed as discussed in the Bases of Technical Specifications 3.2.1B and 3.2.1C. The latest markups of these Bases were previously transmitted to the NRC via letter OG-16-273 (Reference 8). The non-proprietary response Attachment 3 contains a revision to the "Insert 1" text for each of the respective Bases discussions for Technical Specifications 3.2.1B and 3.2.1C.

Method 2 will be used to explicitly calculate the $A_{XY}(z)$ or $A_Q(z)$ factors at the time of the surveillance (as discussed in Sections 4.3.2 and 7.3.2 of the TR, respectively), when these factors are utilized to correct the T(z) or W(z) surveillance factors for the plant operating power level and control rod insertion that are actually present when SR 3.2.1.2 is performed.

However, the option of using Method 1 to set the $A_{XY}(z)$ or $A_Q(z)$ factors to unity (as discussed in Sections 4.3.1 and 7.3.1 of the TR, respectively) will still be retained as an alternative to using Method 2 to explicitly calculate the $A_{XY}(z)$ or $A_Q(z)$ factors at the time of the surveillance. Setting the $A_{XY}(z)$ or $A_Q(z)$ factors to 1.0 is effectively the same as not using them at all. In this respect, using Method 1 is consistent with the current F_Q Surveillance methodology, which makes no correction for surveillances that are performed at conditions different than were assumed in generating the F_Q surveillance factors. The use of Method 1 instead of Method 2 will be optional for any performance of SR 3.2.1.2, but will be necessary if the licensee does not have at least one of the computer codes necessary to perform the calculations as discussed in the response to RAI 15.c.

Section 4.3.1 of the TR states that setting $A_{XY}(z)$ to 1.0, "is a reasonable option that will in all likelihood result in conservative surveillances at off-nominal conditions." As a demonstration of this, Table 7 in the response to RAI 15.e provides a comparison of the minimum margin results obtained from actual plant power distribution measurements which were re-calculated using the T(z) F_Q surveillance methodology, with both Method 1 and Method 2 for determining $A_{XY}(z)$. As seen in Table 7, the Method 1 and Method 2 minimum margin results for the flux maps taken at 6105 and 6510 MWD/MTU at > 99% RTP are within [ ]^{a,c} of each other. For the other five flux maps shown in Table 7, which were taken at near 82% RTP with D-bank inserted approximately 14%, the Method 1 results all conservatively underestimate the actual margin to the F_Q limit by [ ]^{a,c}, compared to the more accurate Method 2 minimum margin results. The actual $A_{XY}(z)$ factors that were calculated using Method 2 for these flux maps are shown in Table 5 of the response to RAI 15.e. Table 5 also contains a set of calculated $A_{XY}(z)$ values for the 6125 MWD/MTU map which assumed that the measurement had been taken at 50% RTP instead of 82% RTP. The resulting $A_{XY}(z)$ values assuming 50% RTP were lower than the $A_{XY}(z)$ values calculated for 82% RTP, and indicate that the use of Method 1 would have produced an [ ]^{a,c} underestimation of the actual margin to the F_Q limit at the limiting elevation of 94-inches, compared to the more accurate Method 2 approach if the measurement had been taken at 50% RTP. The demonstration calculations confirm that the use of Method 1 for determining $A_{XY}(z)$ results in an accurate assessment of the margin to the F_Q limit for nominal core conditions, and also that the use of Method 1 results in a

progressively more conservative underestimation of the available F_Q margin as core conditions vary further away from the nominal conditions. In some cases, it is even possible that the use of Method 1 at different core conditions from nominal could result in a false violation of the F_Q limit.

Section 7.3.1 of the TR states that setting $A_Q(z)$ to 1.0, "is a reasonable option as long as the surveillances are performed such that the AO is near the target." For CAOC plants, the target AO is a *measured* parameter that is established and updated monthly from flux map data taken at the same reference core conditions at which the W(z) factors are defined. The reference core conditions are usually defined as full power, all rods out, equilibrium conditions, unless long term operation is planned at other core conditions. Therefore, flux map measurements taken at the reference core conditions for the purpose of measuring the target AO are, by definition, at the target AO, and are consistent with the W(z) factors. For purposes of discussion, these types of surveillances will be referred to as "nominal" $F_Q^W(z)$ surveillances, and constitute the majority of all $F_Q^W(z)$ surveillances performed at CAOC plants. Nominal $F_Q^W(z)$ surveillances can use Method 1 ($A_Q(z)=1.0$) without affecting the accuracy of the measured $F_Q^W(z)$ margin.

For "off-nominal" $F_Q^W(z)$ surveillances that are not used to measure the target AO in a CAOC plant, the stipulation in Section 7.3.1 of the TR that the AO must be "near the target" must be clarified. If the licensee has identified in advance that an off-nominal surveillance will occur at certain core conditions, then surveillance specific W(z) factors can be generated and included in the COLR in order to support that specific surveillance. An example of this is a planned $F_Q^W(z)$ surveillance performed at a reduced power condition following a refueling outage. In such a case, the use of Method 1 for $A_Q(z)$ at the time of the surveillance, in conjunction with the surveillance specific W(z) factors, would still provide an accurate $F_Q^W(z)$ surveillance result, even if the AO is not near the target. The bases of TS 3.2.1C states that $A_Q(z)$ may be assumed to be 1.0 when the surveillance is performed at the target AO. Thus, if an unanticipated situation arises during a cycle where an $F_Q^W(z)$ surveillance is required to be performed at an off-nominal condition, and Method 1 must be used for determining $A_Q(z)$, then the surveillance must be performed at the target AO. As demonstrated below, if the off-nominal surveillance is performed at an AO within ± 1.5% of the target AO, the results of an $F_Q^W(z)$ surveillance using Method 1 for $A_Q(z)$ will likely be conservative, and the requirement to repeat the surveillance when the power is restored to 100% RTP will provide additional assurance that the F_Q limit will be met during normal operation.

As a demonstration that setting $A_Q(z)$ to 1.0 is an acceptable option for both nominal surveillances performed at the reference core conditions and off-nominal surveillances performed at < 90% RTP where the AO is maintained near the target, Table 9 in the response to RAI 15.f provides a comparison of the minimum margin results obtained from actual plant power distribution measurements which were re-calculated using the W(z) F_Q surveillance method, with both Method 1 and Method 2 for determining $A_Q(z)$. Table 2 in the response to RAI 15.e shows the measured AO data for each of the flux maps shown in Table 9. The AO results from the nominal maps taken at 6105 and 6510 MWD/MTU can be used to establish that the target AO would have been approximately -2.2 % to -2.0% for this plant, if the plant had a CAOC AFD TS. The AO results from all of the other reduced power flux maps are all within ±1.5% of that target AO. The "Original" results shown in Table 9 correspond to using the W(z) F_Q surveillance methodology with Method 1 for the $A_Q(z)$, as there was no correction made to the W(z) factors for the reduced power maps. As seen in Table 9, the Method 1 and Method 2 minimum margin results for the flux maps taken at 6105 and 6510 MWD/MTU at > 99% RTP are within [ ]^{a,c} of each other. For the other five flux maps shown in Table 9, which were taken at near 82% RTP with D-bank inserted approximately 14%, the Method 1 minimum margin results are all more conservative (i.e., result in underestimating the actual available F_Q margin) than the

Method 2 minimum margin results by approximately [ ]^{a,c}. The actual $A_Q(z)$ factors that were calculated using Method 2 for these flux maps are shown in Table 8 of the response to RAI 15.f. From Table 8, it is evident that the majority of the explicitly calculated Method 2 $A_Q(z)$s are < 1.0, and this is why the Method 1 minimum margin results in Table 9 are more conservative. However, Table 8 also demonstrates that $A_Q(z)$ values in axial elevations containing partially inserted Control Bank D can exceed 1.0 by up to [ ]^{a,c}. This indicates that the use of Method 1 could result in a non-conservative estimate of the margin in those axial elevations where Control Bank D is inserted, if the assumed reference core condition at which the W(z) factors were defined did not include this Control Bank D insertion. In order to preclude this possibility, the sample COLR input for a CAOC plant (Appendix F in the TR) will be revised to include a limitation on the use of Method 1 if Control Bank D is inserted deeper than the predicted limiting elevation for $F_Q^W(z)$. The form of this limitation can be either a single defined Control Bank D insertion value, which conservatively bounds the predicted limiting elevation of the $F_Q^W(z)$ for the entire cycle, or a table of Control Bank D insertion versus burnup, which accounts for changes in the predicted limiting elevation with burnup. If the surveillance is performed with Control Bank D above the value defined in the limitation, then the use of Method 1 is acceptable, as there is a reasonable assurance that the minimum $F_Q^W(z)$ margin will be conservatively assessed. Otherwise the use of Method 2 or a surveillance specific W(z) function will be required to be implemented.

Attachment 4 contains a revision to Section F.2.2.6 on Page F-2 of the TR, which revises the affected Section of the sample COLR for a CAOC plant, which includes an example of how this limitation will be implemented. For simplicity, the example provided is for a single bounding value of Control Bank D insertion. However, the limitation could also refer to a table of Control Bank D insertion versus burnup, instead of a single value. This revision to Section F.2.2.6 on Page F-2 of the TR will be made to both the Proprietary and Non-Proprietary versions of the TR.

Response to RAI 15.b (Algebraic Cancellation of $F_{XY}(z)_{Ref}{}^{P}$)

As background for this response, it should be noted that the BEACON™ Core Monitoring System (Reference 1) uses the same neutronic methodologies as those that have been approved by the NRC for the ANC code (see References 2 through 7). This was discussed in the response to RAI #2 for Reference 1. The neutronic methodologies include the methods used to generate the neutron cross sections and perform the core neutronics solution. Since there are multiple variations of the currently approved ANC cross section and pin power methodologies, it is further clarified that the BEACON model will (if used to explicitly calculate $A_{XY}(z)$ or $A_Q(z)$ values) use the same neutronic methodology as the design ANC model that was used as the base model for calculating the F_Q surveillance factors.

Because the W(z) or T(z) factors for the COLR are typically calculated prior to the completion of the previous operating cycle, and prior to manufacturing the feed fuel for the upcoming cycle, the original design models (ODM) used to perform the W(z) or T(z) factor calculations may have some minor differences from the core model ultimately used in BEACON. Typical differences between the final BEACON model and the design ANC model are listed below:

- Use of as-built fuel enrichment and theoretical density in BEACON as opposed to nominal values in the nuclear design model.
- Use of as-built burnable absorber loadings in BEACON as opposed to nominal values in the nuclear design model.
- Use of the actual previous cycle shutdown burnup in BEACON as opposed to using a range of possible burnups for the end of the previous cycle in the nuclear design model. It should be noted that the W(z) or T(z) surveillance factors included in the COLR are generated assuming that the end of the previous cycle will occur within a range of burnups specified by the plant owner (assuming that these factors are calculated before the previous cycle ends). Thus the W(z) or T(z) surveillance factors included in the COLR typically represent the maximum value of two sets of calculated factors which are calculated using nuclear design models that assume different burnups for the end of the previous cycle. If the previous cycle ends within the analyzed burnup window, then the W(z) or T(z) COLR surveillance factors will remain bounding and will not be re-calculated.
- Modeling of reconstituted fuel or damaged fuel substitution in BEACON.

Any significant differences in the core loading pattern that occur during a refueling outage (such as substituting another fuel assembly for a damaged fuel assembly), are evaluated to confirm that the original analysis package for the cycle either remains bounding, or aspects of the analysis will be re-calculated if it does not remain bounding. This evaluation includes the transient F_Q surveillance factors (W(z) or T(z)) that are included in the COLR.

During the performance of an $F_Q{}^W(z)$ surveillance, the above differences may have a small effect on the calculation of $F_{XY}(z)_{Ref}{}^{P}$, such that an exact algebraic cancellation with the denominator in the original T(z) function cannot be guaranteed in all cases. However, these same differences also affect the calculation of $F_{XY}(z)_{Surv}{}^{P}$. The resulting $A_{XY}(z)$ function, which is [ ]^{a,c}, still accurately reflects the relative amount that the predicted $F_{XY}(z)$ distribution will change due to the different surveillance condition. $A_{XY}(z)$ is still sufficiently accurate as long as the core is depleted in the

same manner as the original nuclear design model. The depletion of the core model used to calculate $A_{XY}(z)$ at the time of a surveillance will be constrained to match that of the original nuclear design model, as discussed in the response to RAI 15.d.

As a demonstration of this, one of the example Method 2 $A_{XY}(z)$ calculations performed in the response to RAI 15.e (for the 6125 MWD/MTU flux map) was repeated using the BEACON core model to calculate the $A_{XY}(z)$ values for the map instead of the original design ANC model. The BEACON core model for this plant contains as-built data for the feed fuel region and models the shutdown burnup for the previous cycle. The BEACON model was depleted in the exact same manner as the original design model, without making any corrections for plant measured power distribution data. The $F_{XY}(z)$ calculated data and Method 2 $A_{XY}(z)$ parameters are compared below from the BEACON model and the original design model in Table 1. From Table 7 in the response to RAI 15.e, the minimum margin for SR 3.2.1.2 in the 6125 MWD/MTU map is [ ]^{a,c} when using the Method 2 $A_{XY}(z)$ correction factors calculated from the original design ANC model. When $A_{XY}(z)$ is calculated using the BEACON core model, the minimum margin for SR 3.2.1.2 changes to [ ]^{a,c}. The difference in the SR 3.2.1.2 margin result in this case is less than [ ]^{a,c}.

In comparison, the U_F factor used in this calculation was 8.15% (1.0815), which is obtained by multiplying the 3% manufacturing and 5% measurement uncertainties. As discussed in the response to RAI 4b in Reference 8, the U_F factor includes extra conservatism because the only element of the manufacturing uncertainty not included in the measurement is the pin power factor, and because the axial component of the total uncertainty is known to be conservative due to the use of maximum predicted P(z) results in each axial plane.

The implementation of $A_{XY}(z)$ and $A_Q(z)$ calculations in BEACON will use a very similar nuclear model as the original ANC model used to generate the T(z) or W(z) factors (with minor differences as discussed above). Furthermore, the implementation of $A_{XY}(z)$ and $A_Q(z)$ calculations in BEACON will NOT use the nodal calibration factors and thermocouple corrections which correct the BEACON calculated power distribution results to match the measured power distribution, when BEACON is calculating the two power distribution states necessary to calculate either an $A_{XY}(z)$ or an $A_Q(z)$ correction factor. Finally, in later cycle calculations of $A_{XY}(z)$ and $A_Q(z)$ performed by BEACON, the depletion basis for the cycle to that point will be the same as the original nuclear design model used to calculate the T(z) or W(z) factors, and will not correct for the operational history of the core to that point. With these factors taken into account, and with confirmation that the F_Q surveillance multipliers that are included in the COLR will remain bounded in any redesign situation, the results from SR 3.2.1.2 will remain conservative.

Table 1 – $A_{XY}(z)$ Calculations for Response to RAI 15.b

a,c

Response to RAI 15.c (List of Methods Used to Calculate $A_{XY}(z)$ and $A_Q(z)$)

In addition to the option of using Method 1 (i.e., setting $A_{XY}(z)$ and $A_Q(z)$ to 1.0, which is the same as not using them at all) as discussed in the response to RAI 15.a above, the following methods can be used to calculate explicit $A_{XY}(z)$ and $A_Q(z)$ correction factors by Method 2, using either Equation 4-35 or Equation 7-10 in the TR:

1) For plants that have the BEACON core monitoring system (Reference 1), the BEACON system can be used to calculate either $A_{XY}(z)$ or $A_Q(z)$ when the surveillance is performed. When BEACON is used, the power distribution calculations for calculating $A_{XY}(z)$ or $A_Q(z)$ will be performed without using nodal calibration factors, and the core depletion assumptions will be the same as used in the original core model to generate the T(z) or W(z) factors.

2) ANC (References 2 through 4) can also be used to calculate either $A_{XY}(z)$ or $A_Q(z)$ when the surveillance is performed, using the same nuclear model and depletion basis that was used to generate the original T(z) or W(z) functions.

Response to RAI 15.d (Provide a Specific Description of How BEACON will be Used to Calculate $A_{XY}(z)$ and $A_Q(z)$)

The BEACON model used by licensees contains a full set of cross sections and a beginning of cycle core burnup and isotopic distribution (which is referred to in the discussion below as the "reference" core model). As the cycle depletes, BEACON follows the depletion by simulating depletion steps that match the operating history of the plant, and it also performs calibrations and corrections to the calculated power distribution data based on the plant power distribution measurements. However, BEACON is also capable of depleting the reference core model from the start of the cycle without making any corrections for the plant operating history or power distribution measurements. For the purposes of calculating $A_{XY}(z)$ and $A_Q(z)$ correction factors using Method 2, the reference core model will be depleted without correcting for plant operating history or power distribution measurements, in order to maintain consistency with the original design model used to calculate the T(z)s or W(z)s, as described in the response to RAI 15.b. The following example illustrates how BEACON will be used to calculate either $A_{XY}(z)$ or $A_Q(z)$ using Method 2 for a specific surveillance.

For purposes of this example, it will be assumed that the surveillance is being performed at the core conditions matching the example provided in Table 1 of the response to RAI 15.b. The results shown in Table 1 of the response to RAI 15.b can then be considered a numerical example of calculating $A_{XY}(z)$ using process described below. Specifically the surveillance in this example is assumed to be for a RAOC plant at 82% RTP, 6125 MWD/MTU Cycle Burnup, and Control Bank D inserted to 197 steps withdrawn (SWD), and that the original T(z) functions were generated assuming reference core conditions of hot full power (HFP) and all rods out (ARO), and were based on a depletion performed assuming those same reference core conditions. The steps of the calculation in BEACON would be:

1) The T(z) function will be obtained from the table of available T(z) data at HFP ARO conditions, and interpolated (if necessary) to 6125 MWD/MTU.

2) To calculate $A_{XY}(z)$, BEACON will first deplete the reference core model of the cycle to the burnup associated with the surveillance, assuming HFP, ARO conditions during the depletion.

3) From the depletion in step 2, BEACON will perform a core calculation at 6125 MWD/MTU, HFP, ARO, and Equilibrium Xenon (i.e., the equilibrium xenon condition at HFP, ARO conditions), to duplicate the reference condition assumed in the denominator of the original T(z) function (see Equation 4-14 of the TR). This calculation generates $\mathbf{F_{XY}(z)_{Ref}^{P}}$. Note that in order to maintain consistency with the original design model, no corrections are made to the power distribution results from this calculation based on plant measured power distribution data.

4) From the depletion in step 2, BEACON will perform a core calculation at 6125 MWD/MTU, 82% power, Control Bank D at 197 SWD, and Equilibrium Xenon (i.e., the equilibrium xenon condition at the surveillance conditions). This calculation generates $\mathbf{F_{XY}(z)_{Surv}^{P}}$. Again, in order to maintain consistency with the original design model, no corrections are made to the power distribution results from this calculation based on plant measured power distribution data.

5) The $A_{XY}(z)$ correction is calculated in accordance with Equation 4-35 in the TR [ ]^{a,c}.

6) The $A_{XY}(z)$ function is fit to the axial mesh structure used to process the power distribution measurements.

7) Since the power level of the example surveillance is 82% RTP, BEACON then calculates $F_Q^W(z)$ in accordance with Equation 5-1 in the TR and the result is compared to the $F_Q^W(z)$ limit in accordance with Equation 5-3 in the TR to complete the surveillance. For surveillances where the power level is less than or equal to 50% RTP, Equations 5-2 and 5-4 in the TR are used in place of Equations 5-1 and 5-3, respectively.

In the example above, if the plant were a CAOC plant, the same general process would be used except that the two core calculations in steps 3 and 4 would be used to generate $\mathbf{F_Q(z)_{Ref}^{P}}$ and $\mathbf{F_Q(z)_{Surv}^{P}}$, respectively, and the $A_Q(z)$ factor would be determined in accordance with Equation 7-10 in the TR. The $F_Q^W(z)$ would instead be determined in accordance with Equation 8-1 in the TR (or Equation 8-2 for power levels less than or equal to 50% RTP) and compared to the $F_Q^W(z)$ limit in accordance with Equation 8-4 in the TR (or Equation 8-5 for power levels less than or equal to 50% RTP).

Response to RAI 15.e (Verification of A_{XY} Implementation)

The example discussed below shows the results obtained from actual part power rodded power distribution measurements in a Westinghouse plant. This plant has the RAOC version of the Axial Flux Difference (AFD) and F_Q Technical Specifications. The plant has an F_Q limit of 2.40 from 0 to 6 feet elevation, which reduces linearly from 2.40 to 2.22 between 6 and 12 feet elevation due to a K(z) function. The above values represent the F_Q limit at full power operation. At reduced power operation, the F_Q limit is scaled by the reciprocal of the operating relative power level down to 50% power and remains constant below 50% power.

This plant operated at 82% RTP for approximately 10 days near the middle of a cycle, and experienced low transient $F_Q^W(z)$ margins and even one small spurious $F_Q^W(z)$ violation in the

upper half of the core as a result of the conservative inaccuracy in the current SR 3.2.1.2 surveillance methodology, which was not corrected for the actual surveillance conditions. Prior to the reduced power operation, the plant had operated as planned, at near hot full power (HFP) with control rods at near all rods out (ARO).

This example demonstrates how applying the revised methodology from WCAP-17661 (both with and without Method 2 $A_{XY}(z)$ corrections) would have affected the results from these surveillances. The results without the Method 2 $A_{XY}(z)$ corrections are the same as assuming Method 1 ($A_{XY}(z)$=1.0).

Table 2 shows a summary of the operating power history of the plant during the reduced power phase. Included in Table 2 are the measured transient $F_Q^W(z)$ minimum margin results for the top and bottom halves of the core, and the measured minimum steady state $F_Q^C(z)$ minimum margin results obtained from the flux maps taken at the plant, which used the current RAOC-W(z) methodology. The purpose of showing the measured $F_Q^C(z)$ minimum margin is to demonstrate that the unit never actually operated anywhere close to the F_Q limit used in the safety analysis. Table 2 also shows the measured and predicted axial offset (AO) and the predicted transient $F_Q^W(z)$ minimum margin results from the original RAOC analysis models at the burnups of interest. The predicted AO is based on the depletion model, which assumed HFP, ARO reference conditions. All measured and predicted margin results in Table 2 contain the standard 8.15% uncertainty applied, and no R_J penalty factor.

Table 3 shows the COLR W(z) functions that were applicable to this core, and the results of interpolating the W(z) functions to the burnups of interest. For each axial elevation, the W(z) functions were interpolated to the burnup of interest using a spline fit between three burnup dependent data points from the W(z) table. W(z) values in the top and bottom surveillance exclusion zones are shown as Not Applicable (N/A).

Table 4 shows the equivalent calculated T(z) functions for this core. The T(z) functions were generated using the methodology described in the TR and using the original core model that generated the W(z) functions. The T(z) functions shown in Table 4 represent the T(z) values for this plant if it had implemented WCAP-17661-P at the time these power distribution measurements were performed. Table 4 also shows the T(z) functions interpolated to the burnups of the flux maps.

Table 5 shows $F_{XY}(z)$ and $A_{XY}(z)$ values calculated for each flux map, using the original ANC model that generated the COLR W(z) data. Both the reference and the surveillance specific $F_{XY}(z)$ calculation results are shown in Table 5. In this table, Method 2 was used to generate the $A_{XY}(z)$ values. The original ANC model was depleted to the burnups of various surveillances at ARO, HFP conditions, in the same manner that BEACON would perform these calculations at the plant (see RAI 15.d response). Table 5 also includes an extra calculation that shows what the calculated $A_{XY}(z)$ values would have been if the flux map at 6125 MWD/MTU had been performed at 50% RTP and Control Bank D at 155 SWD instead of 81.8% RTP and Control Bank D at 197 SWD. The purpose of this extra calculation is to demonstrate that the $A_{XY}(z)$ values become significantly more important in the top of the core as power is reduced further and Control Bank D is inserted further into the core to maintain the target axial flux difference (AFD) close to the normal HFP AFD.

Tables 6a through 6g show the $F_Q^W(z)$ surveillance calculations performed for each flux map using the original RAOC W(z) methodologies and the WCAP-17661-P methodologies, both with and without the Method 2 $A_{XY}(z)$ values applied. The results are shown for each axial elevation.

Each table includes the measured $F_Q(z)$ and $F_{XY}(z)$ distributions from each flux map, as well as the calculated $F_Q^W(z)$ results using the original RAOC W(z) methodology and the WCAP-17661 methodologies. Since there were no actual measurements performed for the 6125 MWD/MTU flux map at the 50% RTP condition, there is no corresponding Table 6 presented for the extra hypothetical $A_{XY}(z)$ calculation included in Table 5.

Table 7 summarizes the results of all the calculations performed in Tables 6a through 6g. With respect to the R_J penalty factor, none of the results shown in Table 7 include an R_J penalty. As noted in the response to RAI 13a in Reference 8, the R_J penalty factor may be developed based on the SR 3.2.1.2 surveillance frequency, and this plant was processing flux maps more than once per day during part of the reduced power phase. The predicted value of R_J at the burnups of the example flux maps, for a 31 day surveillance frequency, was approximately 0.5% (R_J=1.005). If the Method 1 and 2 results shown in Table 7 included the R_J penalty associated with a 31 day surveillance interval, the margins would be reduced by 0.5%.

The results in Table 7 confirm the following conclusions:

1) Using Method 1 to determine the $A_{XY}(z)$ factor would have been conservative (relative to using Method 2 to explicitly calculate the $A_{XY}(z)$ factor) for all of the surveillances in this case.

2) The use of Method 1 and Method 2 to determine the $A_{XY}(z)$ factor produced essentially the same results (within 0.1%) for the minimum margins for those flux maps that were performed at greater than 99.5% RTP with Control Bank D inserted to 225 SWD. For the reduced power flux maps, the use of Method 2 demonstrated 0.3% to 0.7% more available margin than Method 1.

3) The Method 2 results shown in Table 7 are the most accurate indication of the true measured $F_Q^W(z)$ margin when these power distribution measurements were performed. The measured margin in the top of the core is less than the predicted margin because the plant was measuring larger $F_{XY}(z)$ values in the top of the core when these measurements were performed.

4) The small violation of the measured $F_Q^W(z)$ shown in the 6125 MWD/MTU flux map using the original RAOC W(z) methodology was a false violation. As evidenced by the measured $F_Q^C(z)$ margin in Table 2, the actual operating margin to the safety analysis limit increased by more than 10% when core power was reduced to 82% RTP and Control Bank D was inserted to 197 SWD. The false violation of $F_Q^W(z)$ was caused by the combination of two effects, both of which are corrected by the full implementation of the methodology contained in WCAP-17661-P:

    a. The $F_Q(z)$ distribution was measured at a power level of 82% RTP with Control Bank D inserted to 197 SWD, which was not consistent with the assumed HFP, ARO reference core condition used to calculate the denominator of the W(z) factor. The measured F_Q at the elevation of the apparent $F_Q^W(z)$ violation was therefore increased. Had the W(z) denominator been calculated assuming the surveillance would occur at the actual surveillance condition, the W(z) at that elevation would have been smaller, because of a similar increase in the predicted F_Q at that elevation. This effect is the major cause of the apparent decrease in $F_Q^W(z)$ margin in the upper half of the core between the power distribution measurements performed at 6105 MWD/MTU and 6125 MWD/MTU.

b. The measured axial power distribution from the power distribution measurement performed at 6125 MWD/MTU was slightly more positively skewed than the predicted axial power distribution. This also resulted in a small increase in the measured $F_Q(z)$ values in the upper half of the core, which contributed in a small way to the apparent $F_Q^W(z)$ violation. In the later measurements that were performed at reduced power conditions, the measured axial power distribution is more negatively skewed than predicted, and the result was an apparent increase in $F_Q^W(z)$ margin in the upper half of the core, which was just enough to clear the false $F_Q^W(z)$ violation.

5) The hypothetical $A_{XY}(z)$ calculations performed for the 6125 MWD/MTU flux map assuming power was at 50% RTP and Control Bank D was inserted to 155 SWD (See the final set of calculations shown in Table 5) demonstrate that if the plant had operated at these conditions, the $F_Q^W(z)$ surveillance results would underestimate the true available $F_Q^W(z)$ margin by up to 8% in the axial elevations containing Control Bank D, if Method 1 were used instead of Method 2. When Control Bank D is inserted to 155 SWD, the control rods are inserted approximately 44 inches into the core, and the smallest $A_{XY}(z)$ values occur in the top 30-inches of the core. At the limiting margin elevation determined in the original flux map (94 inches), which would be just below the Control Bank D tip at 155 SWD, the hypothetical $A_{XY}(z)$ calculations in Table 5 indicate that the use of Method 1 would underestimate the available $F_Q^W(z)$ margin by [ ]^{a,c}. In comparing this to the margin results shown in Table 6b, it is unlikely that this would have caused an $F_Q^W(z)$ violation in this particular case. This is because there is greater than [ ]^{a,c} margin to the $F_Q^W(z)$ limit in the top 30 inches of the core, and greater than [ ]^{a,c} margin to the $F_Q^W(z)$ limit at the 94-inch elevation at this point in the cycle. However, if the 50% power reduction had occurred at a later point in the cycle, where margins are reduced in the upper and lower axial elevations of the core, there is a potential that a false violation of $F_Q^W(z)$ would occur if either Method 1 is used for determining $A_{XY}(z)$, or if Method 2 is used with a restriction that excludes applying $A_{XY}(z)$ values less than 1.0. If Method 2 is applied without such a restriction, as described in Section 4.3.2 of the TR, then the $F_Q^W(z)$ margin can be accurately determined in the axial elevations containing Control Bank D for the reduced power operating condition.

Response to RAI 15.f (Verification of A_Q Implementation)

The example discussed in the response to RAI 15.e above includes surveillance calculations performed with W(z) factors and no $A_Q(z)$ correction factors. These results are identical to using Method 1 for determining $A_Q(z)$ (i.e., setting $A_Q(z)$ to 1.0).

Using the same core models used in generating the Method 2 $A_{XY}(z)$ factors in Table 5, the Method 2 $A_Q(z)$ factors were generated for this set of flux maps in Table 8.

Table 9 then contains updated W(z) based surveillance results after applying the Method 2 $A_Q(z)$ correction factor.

The results confirm again that the use of Method 1 for determining the $A_Q(z)$ factor resulted in a conservative surveillance for all of the flux maps, although there is essentially no difference in the results for the flux maps that were performed at near HFP ARO conditions. When the Method 2 $A_Q(z)$ correction factors are applied, the results of the surveillance are significantly improved (i.e., more margin to the limit) at the reduced power conditions.

As discussed in the response to RAI 15.e above, the false $F_Q^W(z)$ violation in the 6125 MWD/MTU flux map results from using the W(z) methodology without applying an $A_Q(z)$ correction factor, which is equivalent to using Method 1 to determine the $A_Q(z)$. Table 9 shows that the violation is resolved if Method 2 is used to calculate the $A_Q(z)$ correction factor, as described in Section 7.3.2 of the TR. However if Method 2 is applied with a restriction that excludes applying $A_Q(z)$ values less than 1.0, then the false $F_Q^W(z)$ violation would remain for the measurement performed at 6125 MWD/MTU.

References for RAI 15 Responses

1) WCAP-12472-P-A, Addendum 4, "BEACON™ Core Monitoring and Operation Support System."

2) WCAP-10965-P-A, "ANC – A Westinghouse Advanced Nodal Computer Code."

3) WCAP-10965-P-A, Addendum 1, "Enhancements to Rod Power Recover."

4) WCAP-10965-P-A, Addendum 2, "Qualification of New Pin Power Recovery Methodology."

5) WCAP-16045-P-A, "Qualification of the Two-Dimensional Transport Code PARAGON."

6) WCAP-16045,P-A, Addendum 1, "Qualification of the NEXUS Nuclear Data Methodology."

7) WCAP-11596-P-A, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," June 1988.

8) OG-16-273, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC F_Q Surveillance Technical Specifications, PA-LSC-0795."

Table 2 – Operating Power History of Unit and Original Predicted $F_Q^W(Z)$ Margins

[ ]a,c

Table 3 – COLR W(z,Bu) Functions and Interpolated W(z)s Used in Flux Maps a,c

Table 4 – T(z,Bu) Functions and Interpolated T(z)s Used in Flux Maps

a,c

Table 5 – $A_{XY}(z)$ Calculations for Flux Maps Using Method 2

a,c

Table 5 (Continued) – $A_{XY}(z)$ Calculations for Flux Maps Using Method 2 **a,c**

Table 5 (Continued) – $A_{XY}(z)$ Calculations for Flux Maps Using Method 2 a,c

Table 6a – Calculation of $F_Q^W(z)$ at 6105 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (99.8% RTP, Control Bank D at 225 SWD)

a,c

Table 6b – Calculation of $F_Q^W(z)$ at 6125 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (81.8% RTP, Control Bank D at 197 SWD)

a,c

[ ]

Table 6c – Calculation of $F_Q^W(z)$ at 6168 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (81.9% RTP, Control Bank D at 193 SWD)

a,c

Table 6d – Calculation of $F_Q^W(z)$ at 6201 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (82.1% RTP, Control Bank D at 193 SWD)

a,c

Table 6e – Calculation of $F_Q^W(z)$ at 6250 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (81.9% RTP, Control Bank D at 193 SWD)

a,c

[ ]

Table 6f – Calculation of $F_Q^W(z)$ at 6376 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (80.6% RTP, Control Bank D at 192 SWD)

a,c

Table 6g – Calculation of $F_Q^W(z)$ at 6510 MWD/MTU Burnup Using Various F_Q Surveillance Methodologies (99.6% RTP, Control Bank D at 225 SWD)

a,c

Table 7 – Summary of Transient $F_Q^W(z)$ Margin Results for All F_Q Surveillance Methodologies Used for RAOC Plants

[ ] a,c

Table 8 – $A_Q(z)$ Calculations for Flux Maps Using Method 2

a,c

Table 8 (Continued) – $A_Q(z)$ Calculations for Flux Maps Using Method 2 **a,c**

Table 8 (Continued) – $A_Q(z)$ Calculations for Flux Maps Using Method 2

a,c

Table 9 – Summary of Transient $F_Q^W(z)$ Margin Results for All F_Q Surveillance Methodologies Used for CAOC Plants

a,c

RAI-15 Response for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795) (Non-Proprietary)

Markup of Affected WCAP-17661-NP Sections to Delete References to Methods 3 and 4 for Generating AXY(z) and Method 3 for Generating AQ(z)

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4.3 CALCULATION OF $A_{XY}(Z)$ AND ITS SUB-FACTORS

For the vast majority of surveillances in the vast majority of plants, the $A_{XY}(z)$ adjustment factors will be unimportant. The reasons for this are:

1. Virtually all plants are operated in baseload mode at nominal operating conditions with control rods nearly fully withdrawn. Consequently, if the reference conditions assumed for generating the T(z) values are HFP, ARO, EQXE, these conditions will usually agree closely with the actual surveillance core conditions. So, $F_{PC}(z)$ and $F_{RC}(z)$ will very nearly equal 1.0; therefore, $A_{XY}(z)$ will nearly equal 1.0.

2. For surveillances, many plants use a core model from an on-line core monitoring system that has been calibrated to the measured core via periodic flux maps and continuous readings from incore and excore instrumentation (e.g., excore detectors, thermocouples, or fixed incore detectors). The power distribution in the calibrated core model is effectively the measured power distribution. During a surveillance, this calibrated core model is taken to HFP, ARO, EQXE conditions. The resulting $F_Q(z)$ from that model is the measured $F_Q(z)$ used in the F_Q Surveillance formulation. For these plants, then, every surveillance is at the correct reference conditions; therefore, $A_{XY}(z)$ will always equal 1.0.

3. As Tables 3-1 and 3-2 show, the power distribution sensitivity of the radial peaking factor is not large. For, power levels ≥ 70% RTP, the ratio of the full power F_{XY} to the part power F_{XY} (which is F_{PC}) was > 0.98, which corresponds to a less than 2% correction.

4. Tables 3-3 and 3-4 show that F_{RC}, the peaking factor correction for control rods, can be significant. However, at high power levels, the lead control bank is rarely inserted deeply. Furthermore, the axial location of the minimum margin is rarely in the small region at the top of the core where the lead control bank could be present.

5. The current F_Q Surveillance formulation does not include the $F_{PC}(z)$ and $F_{RC}(z)$ corrections, even though it legitimately could (see Section 7). Despite this, F_Q margin issues occur very infrequently, which implies that ignoring these effects does not pose significant difficulties in meeting limits for the vast majority of surveillances.

6. Technical Specifications require re-verification of transient $F_Q(z)$ whenever power is increased by more than 10% relative to the last verification of $F_Q(z)$. Consequently, surveillances will always occur at high powers near the core conditions assumed in generating the COLR T(z) factors and where transient F_Q margin is near its minimum value.

Given these six reasons, a good argument could be made that explicit inclusion of the $A_{XY}(z)$ factors in surveillances is unnecessary. However, use of these factors should be an option in the rare circumstance where a plant needs margin to avoid an operating space or power level reduction. With this in mind, several methods are discussed in the following subsections for incorporating these adjustment factors into surveillances. They are discussed in order of increasing complexity.

This method will be included in the COLR as an appropriate method to account for differences between the reference and surveillance conditions in the surveillance transient F_Q margin assessment. If this method is used, the values will be determined on a surveillance specific basis. Note that the values of $A_{XY}(z)$ will not be included in the COLR; rather, only the method will be referenced.

4.3.3 Method 3: Limited Pre-calculation of $F_{PC}(z)$ and $F_{RC}(z)$ with Simplifying Assumptions

It is possible to include pre-calculated values for $F_{RC}(z)$ and $F_{PC}(z)$ in the COLR. However, to do this for all possible power levels, control rod positions, and cycle burnups is not realistic. Instead a limited set of values could be included in the COLR for a specific cycle burnup or range of cycle burnups and employing some simplifying assumptions to reduce the scope of reactor conditions presented in the COLR to something practical.

Surveillances for off-nominal conditions are most likely to be performed during the initial startup following a refueling. Consequently, if specific values for $F_{RC}(z)$ and $F_{PC}(z)$ are desired for inclusion in the COLR, it would be most useful to determine values to support surveillances during the initial power ascension.

The required table of values can be considerably reduced if the following simplifying assumption is made: Because of feedback effects, increases in radial peaking factors due to insertion of the lead control bank at full power will generally be less than for the same insertion at part power. Another way to state this is the following:

$$\frac{F_{XY}(z,1.0,ARO)}{F_{XY}(z,1.0,R_{Surv})} \geq \frac{F_{XY}(z,P_{Surv},ARO)}{F_{XY}(z,P_{Surv},R_{Surv})} \qquad when\ P_{Surv} \leq 1.0 \qquad (4\text{-}36)$$

or

$$F_{RC}(z, 1.0) \geq F_{RC}(z, P_{Surv}) \qquad when\ P_{Surv} \leq 1.0 \qquad (4\text{-}37)$$

Table 4-1 provides values for $F_{RC}(z, P_{Surv})$ at BOL for a range of relative powers from 1.0 to 0.7 for a typical 4-loop core. The values were generated by assuming complete insertion of the lead control bank to quantify the effect of the control rod at each axial elevation. The table also provides ratios of $F_{RC}(z, 1.0)$ to $F_{RC}(z, P_{Surv})$. Note that, except for the very top of the core, $F_{RC}(z, P_{Surv})$ decreases with power level. Typically, the exclusion zone for F_Q Surveillance is the top and bottom 15% of the core, although smaller exclusion zones are sometimes specified. Estimates of the transient F_Q are not required in these regions due to the difficulty of obtaining an accurate measurement there and the small likelihood of limiting margins in these regions. Consequently, these $F_{RC}(z, P_{Surv})$ values near the top of the core would usually be in the upper exclusion zone and, therefore, would not be employed. Regardless, assuming that the values for full power are limiting is generally a good assumption resulting in either conservative values or values that are trivially non-conservative. Even the trivially non-conservatisms can be eliminated by simply assuming the maximum values of $F_{RC}(z, P_{Surv})$ over the range of power levels considered. The maximum values are also indicated in Table 4-1.

The above strategy results in a single set of $F_{RC}(z)$ values applicable at BOL for the startup surveillances. Of course, the maximum insertion of the lead control bank is a function of power level and is specified in the COLR. Deeper rod insertions are permitted at lower power levels. While Table 4-1 illustrates values of $F_{RC}(z)$ over a full range of core heights, in practice $F_{RC}(z)$ will be approximately equal to 1.0 for unrodded core planes. For example, for the particular core used here, the Control Bank Insertion Limits specify that the deepest permitted insertion for the lead control bank (D-Bank) at 70% RTP is a core height of approximately 5.1 feet. Consequently, values of $F_{RC}(z)$ below this height would always be ~1.0. Values for core planes above this height would also be ~1.0 if the particular core plane is unrodded at the surveillance condition.

To obtain values for the power correction factor, $F_{PC}(z)$, expression (4-21) is used. When the reference rod position is specified as ARO, we have the following:

$$F_{PC}(z, P_{Surv}) = \frac{F_{XY}(z, P_{Ref}, ARO)}{F_{XY}(z, P_{Surv}, ARO)} \quad (4\text{-}38)$$

Table 4-2 gives example values for $F_{PC}(z, P_{Surv})$ for a range of power levels at BOL for the same 4-loop core design used for Table 4-1. Equilibrium xenon was assumed in calculating these values. As noted earlier, these values are not a strong function of power level at BOL. A significantly larger sensitivity to power level is evident later in life (see Table 3-2). For BOL, all the values are within 1% of 1.0.

Tables 4-1 and 4-2 give values for these factors at core heights corresponding to the nodes in the 3D core model used to calculate them. In this model, 26 axial nodes were used. Typically, surveillances are performed over a larger number of evenly spaced axial positions. In a typical flux map, 61 axial points are usually used. Values for these factors at the specific surveillance axial positions can be obtained by interpolating on the nodal values using standard interpolation methods. Similarly, Table 4-2 gives $F_{PC}(z, P_{Surv})$ values only for a small set of power levels. Values for intermediate powers can be obtained using standard interpolation methods. If, however, a surveillance is performed at a power level lower than the minimum power level in the table, the values of $F_{PC}(z, P_{Surv})$ for the minimum power level in the table should be used rather than extrapolating the table values to lower powers.

Tables 4-1 and 4-2 were generated specifically for BOL. In principle, however, similar values could be generated for any specific cycle burnup or range of cycle burnups. Interpolation on burnup could then be performed. For example, if a part-power surveillance became necessary late in life, $F_{RC}(z)$ and $F_{PC}(z)$ could be pre-calculated at the burnup of interest or over a range of burnups near the burnup anticipated for the surveillance. These values could then be included in the COLR, either when the COLR was initially prepared or through a COLR update.

Note that this method assumes that the power and control rod correction factors are separable, i.e., independent of one another. In reality, there are 3D effects that can occur, especially near the transition region between the rodded and unrodded core planes. In this region, the presence of the control rods can affect the limiting radial peaking factors in unrodded core planes just below the control rods and vice versa. These 3D effects will be small if the radial location of the peak is not near the control rod locations. In this case, insertion of the control rod will normally increase the peaking factor. When the peak radial location is near the control rod, insertion of the control rod can reduce the radial peaking factor in both the rodded planes and in the unrodded planes in the transition region. In this case, the

product of $F_{RC}(z)$ and $F_{PC}(z)$ could be underestimated. This would result in an overestimation of the margin in this region. It is judged, however, that, in practice, this is very unlikely to result in any significant non-conservative minimum margin assessments since control rods are typically not deeply inserted during surveillances, except possibly for low power surveillances. Furthermore, low power surveillances are really only interim assessments; new surveillances must be performed when reactor power is increased by greater than or equal to 10% RTP above the power level of the most recent surveillance. Also, core designers can readily determine whether this method will provide sufficiently accurate assessments. Method 2 or Method 4 (see subsection 4.3.4) could be used if accuracy is judged to be an issue.

4.3.4 Method 4: Pre-calculation of $A_{XY}(z)$

The last method for calculating these correction factors involves direct calculation of the product of $F_{RC}(z)$ and $F_{PC}(z)$, i.e., $A_{XY}(z)$, using expression (4-22). This is essentially the same as Method 2 but instead of calculating surveillance specific factors at the time of the surveillance using an approved core model, the factors are pre-calculated and included in the COLR. (Alternatively, the COLR can be updated to include these factors prior to the surveillance.) As discussed above, to do this for all core power levels, lead bank positions, and cycle burnups is not very practical or even necessary. However, similar to the approach in the previous subsection, values could be determined for startup, for a specific expected surveillance condition, or for a specific cycle burnup or range of cycle burnups.

Tables 4-3 through 4-6 give startup values for the same core used in the previous example. Each table gives $A_{XY}(z)$ values for a different core relative power. Specifically, the relative power levels considered were 1.0, 0.9, 0.8, and 0.7 for Tables 4-3 through 4-6, respectively. Also, each table considers various D-Bank positions ranging from fully withdrawn to an insertion slightly deeper than the insertion limit for that power level. Increments of 20 steps were used (1 step = 0.625 inches). Of course, different power and rod position increments could be used, e.g., power increments of 0.05 and rod position increments of 10 steps. It would be useful for the tables to include rod positions frequently used for flux maps. For example, if flux maps frequently occur with the lead bank at ≥210 steps withdrawn, then including data for a rod position of 210 steps would be advantageous.

If a surveillance is performed at some intermediate state that does not correspond exactly to any of the conditions assumed in the table, then the following process is recommended: As an example, suppose a surveillance is performed at 85% RTP (0.85 relative power) and with D-Bank at 195 steps withdrawn. To obtain $A_{XY}(z)$ values appropriate for these conditions, a reasonable process would be to interpolate between the tables to obtain values by rod position for 85% RTP. Next, the maximum $A_{XY}(z)$ values between the two sets at 205 steps and 185 steps would be used. In some circumstances, this process may conservatively underestimate the available margin in the transition region between the rodded and unrodded core planes. Interpolation on rod position is not really appropriate, however, because the variability of the factors is not a smooth function of rod position.

Some of the $A_{XY}(z)$ values in Tables 4-3 through 4-6 exceed 1.0 by a few percent. For example, in Table 4-5, the value for a D-Bank position of 185 steps withdrawn (SWD) and a core height of 9.81 ft is 1.027. As discussed in the previous subsection, this can occur in cases where the presence of the control rod suppresses the radial peaking factor. In this particular instance, the peak unrodded $F_{XY}(z)$ is very near a D-Bank control rod location. Consequently, inserting the control rod reduces the radial peaking factor.

This local peaking factor suppression can occur in both the rodded planes and in the unrodded planes near the tip of the control bank. A control rod position of 185 SWD corresponds to a core height of 10.0 ft. Thus, core planes above and immediately below this elevation are affected by the control rod's presence. The same phenomenon is observable for the other rod positions, but at different axial locations since the rod positions are different.

One option is to simply exclude core planes from the surveillance that are near the bank demand position. This exclusion is, in fact, included in the Bases for SR 3.2.1.2 of Technical Specification 3.2.1A in Reference 1, which is the Heat Flux Hot Channel Factor Technical Specification for CAOC $F_{XY}(z)$ plants. This exclusion will be retained in the Bases for the improved F_Q TS. (See additional discussion on this in the following section.) This exclusion is justified because the limiting margin location is very unlikely to be in or near a rodded plane. As will be shown in Section 6, the elevation of the limiting transient F_Q margin for this core at BOL is 7.65 ft. This is well below any elevation that would be significantly affected by control rods for a surveillance at or near full power. Furthermore, for the vast majority of high power surveillances, control rod insertion is very minimal. Consequently, the limiting margin location is rarely in a region where control rod influences will obscure the minimum margin assessment. For this particular core, any of above methods would give good minimum transient F_Q margin assessments for high power surveillances.

4.4 MEASUREMENT OF $F_{XY}(Z)$

In this new formulation, the key factor being measured is the $F_{XY}(z)$. The measured $F_{XY}(z)$ is used to normalize the transient $F_Q(z)$ analysis to the radial peaking factors of the measured core. Of course, $F_{XY}(z)$ is being measured in the current formulation, too, but as a component of the measured $F_Q(z)$. The measured $F_{XY}(z)$ can be directly obtained from the measured $F_Q(z)$ through use of expression (2-10), i.e.:

$$F_{XY}^{M}(z) = \frac{F_Q^M(z)}{P^M(z)} \tag{4-39}$$

There are a number of plants (primarily CAOC plants) that confirm $F_Q(z)$ indirectly by measuring $F_{XY}^M(z)$ and then comparing this measurement to an $F_{XY}(z)$ limit. These plants utilize the surveillance approach discussed in Technical Specification 3.2.1A in Reference 1, which, as mentioned earlier, is the Heat Flux Hot Channel Factor Technical Specification for CAOC $F_{XY}(z)$ plants. The bases for this TS specify that core plane regions within ±2% of the grid plane regions are excluded from the surveillance. The 2% value corresponds to 2% of the core height or about 2.9 inches for a 12 foot core. The reason for this exclusion is a concern with respect to measuring F_{XY} in this region. If the flux traces from the moveable detector system are not all well-aligned with respect to their grid depressions, it is possible to get "anomalous" F_{XY} measurements. This could occur, for example, if a flux trace were misaligned such that a non-grid axial point was mispositioned into a grid plane. This would cause the measured F_{XY} for that grid plane to be unrealistically large, resulting in an anomalous margin reduction relative to the F_{XY} limit.

For the current formulation, where $F_Q(z)$ is measured, this issue is not much of a problem since the axial powers at the grid elevations are depressed. Even if the measured F_{XY} is anomalously large at a grid plane because of a trace misalignment or other measurement difficulty, the effect is offset by the grid depression. There are no grid exclusions in the current F_Q Surveillance TS.

Table 4-1 $F_{RC}(z, P_{Surv})$ Values at BOL for a Range of Relative Powers

a,c

Note:
1. Values are applicable for the initial ascension to full power for burnups less than or equal to 150 MWD/MTU.

Table 4-2 $F_{PC}(z, P_{Surv})$ Values at BOL for a Range of Relative Powers

a,c

Note:
1. Values are applicable for the initial ascension to full power for burnups less than or equal to 150 MWD/MTU.

Table 4-3 Method 4: $A_{XY}(z)$ Values at BOL for a Relative Power of 1.0

a,c

Table 4-4 Method 4: $A_{XY}(z)$ Values at BOL for a Relative Power of 0.9

a,c

Table 4-5 Method 4: $A_{XY}(z)$ Values at BOL for a Relative Power of 0.8

a,c

Table 4-6 Method 4: $A_{XY}(z)$ Values at BOL for a Relative Power of 0.7

a,c

6.4 $A_{XY}(Z)$ VALUES FOR INITIAL POWER ASCENSION

As discussed in Section 4.3, the $A_{XY}(z)$ factors adjust the measured $F_{XY}(z)$ for consistency with the reference core conditions used to generate the COLR T(z) values. The vast majority of surveillances are performed at high power conditions during the operating cycle with control rods nearly fully withdrawn. For these surveillances, the $A_{XY}(z)$ will generally be very close to 1.0 at nearly all elevations and, in particular, at elevations where transient F_Q margin is likely to be limiting. Furthermore, for the particular core used in this example, ample transient F_Q margin is anticipated. This is evident from the $F_Q(z)$*Power plots in Figures 6-4 though 6-7. Therefore, an assumption of $A_{XY}(z)$ equal to 1.0 is reasonable.

Section 4.3 presented values of these $A_{XY}(z)$ factors for the initial power ascension calculated using two different methods. Method 3 assumed that the $F_{PC}(z)$ and $F_{RC}(z)$ subfactors of $A_{XY}(z)$ were separable. These subfactor values were presented in Tables 4-1 and 4-2. In Tables 4-3 through 4-6, pre-calculated values of $A_{XY}(z)$ were determined using Method 4 for various surveillance power levels and control rod positions. The values in Tables 4-3 through 4-6 were tabulated for the axial mesh of the 3D core model used to calculate them. Tables 6-5 through 6-8 present these factors interpolated to the surveillance axial mesh, which for this core consists of 61 evenly spaced axial points. In these tables, $A_{XY}(z)$ was set to 0.0 for the top and bottom exclusion zones.

Tables 6-5 through 6-8 present these $A_{XY}(z)$ values as they might appear in the COLR. Obviously, this method is somewhat awkward given the large number of values that must be pre-calculated and the need to determine appropriate values for intermediate power levels and rod positions.

A convenient method for determining these factors is Method 2 using expression (4-35). In this method, the factors are not included in the COLR. Instead, they are determined for the specific surveillance conditions at the time of the surveillance using an approved 3D core model. In this example analysis, this is the method that will be used.

Section 6.6 will describe the application of this improved F_Q Surveillance formulation to a specific flux map. The flux map was taken at a cycle burnup of 221 MWD/MTU. The core relative power was 0.999, and the D-Bank location was 228 SWD. Table 6-9 gives the $A_{XY}(z)$ values determined using Method 2 and interpolated to the surveillance axial positions. In this case, the flux map was taken at core conditions that are nearly the same as the reference core conditions. Consequently, the $A_{XY}(z)$ values are nearly equal to 1.0 (within about 0.1%), indicating that, for this particular surveillance, essentially no adjustment of the measured radial peaking factors is necessary for consistency with the reference conditions assumed for the COLR T(z) values.

6.5 POWER AND AFD REDUCTIONS

As discussed in Section 5.3, if no ROS included in the COLR provides the required margin improvement when $F_Q^W(z)$ exceeds its limit, then Required Action B.2.1 and the COLR will specify limits on thermal power and required reductions in AFD. Optionally, these reductions may be implemented instead of employing a more restrictive ROS. [

]^{a,c} The minimum margin improvement relative to the reference analysis for that ROS will be determined. The

Table 6-5 Initial Power Ascension $A_{XY}(z)$ for Relative Power of 1.0

a,c

Table 6-6 Initial Power Ascension $A_{XY}(z)$ for Relative Power of 0.90

a,c

Table 6-7 Initial Power Ascension $A_{XY}(z)$ for Relative Power of 0.80

a,c

Table 6-8 Initial Power Ascension $A_{XY}(z)$ for Relative Power of 0.70

a,c

inserted. At EOL, $F_{XY}(z)$ is increased more than P(z) is suppressed in the rodded region, resulting in $A_Q(z)$ values less than 1.0. Consequently, the $A_Q(z)$ values are very different at the top of the core for BOL and EOL.

While the axial offsets are the same for the reference and surveillance cases, the P(z) shapes, while very similar, are not exactly the same. Figure 7-1 shows the axial power shapes for the four core conditions of Table 7-1. The subtle differences between the reference and surveillance P(z) shapes influence the $A_Q(z)$ values. In unrodded axial planes where the reference P(z) exceeds the surveillance P(z), the $A_Q(z)$ values will tend to be greater than 1.0.

7.3.3 Method 3: Pre-calculation of $A_Q(z)$ for the Surveillance Condition

Just as the values for $A_{XY}(z)$ can be pre-calculated as described in subsection 4.3.4, values of $A_Q(z)$ can be pre-calculated for multiple surveillance conditions using expression (7-10) and included in the COLR in tables similar to Table 4-3 through 4-6. While this is possible in theory, as a practical matter it is cumbersome due to the wide range of surveillance conditions. Note that as an equivalent alternative, surveillance specific W(z) values can be calculated and included in the COLR. This is currently done to support specific startup surveillances for some cores.

7.4 CRUD INDUCED POWER SHIFT CONSIDERATIONS FOR CAOC CORES

Section 4.5 discussed CIPS considerations and indicated that the T(z) and W(z) factors can be affected by CIPS. Specifically, CIPS can affect the maximum transient P(z), which appears in the numerator of both the T(z) and W(z) expressions. The recommendations of Section 4.5 apply to CAOC cores. To reiterate, it is proposed that, should CIPS occur, the effect of CIPS on transient F_Q margin should be addressed in a timely fashion, e.g., within several weeks of the observed onset. This is proposed rather than the application of generic CIPS penalty factors that are a function of ΔAO.

Attachment 3

Revision to "Insert 1" in the Bases Markups

for TS 3.2.1B and TS 3.2.1C

that were transmitted via OG-16-273

(3 pages including Attachment 3 cover page)

$A_{XY}(z)$ is a function that adjusts the $F_Q^W(z)$ Surveillance for differences between the reference core condition assumed in generating the $[T(z)]^{COLR}$ function and the actual core condition that exists when the Surveillance is performed.

Revised INSERT #1 for Bases B 3.2.1B

The various factors in this expression are defined below:

$F_{XY}^M(z)$ is the measured radial peaking factor at axial location z and is equal to the value of $F_Q^M(z)/P^M(z)$, where $P^M(z)$ is the measured core average axial power shape.

$[T(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[T(z)]^{COLR}$ functions are specified for each analyzed RAOC operating space (i.e., each unique combination of AFD limits and Control Bank Insertion Limits). The $[T(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each RAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[T(z)]^{COLR}$. The $[T(z)]^{COLR}$ functions also account for the following effects: (1) the presence of spacer grids in the fuel assembly, (2) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (3) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (4) the increase in radial peaking due to non-equilibrium xenon effects. The $[T(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at nominal RTP conditions with all shutdown and control rods fully withdrawn, i.e., all rods out (ARO). Surveillance specific $[T(z)]^{COLR}$ values may be generated for a given surveillance core condition.

100% RTP, all rods out, and equilibrium xenon.

P is the THERMAL POWER / RTP.

~~$A_{XY}(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_{XY}^M(z)$ to the reference core conditions assumed in generating the $[T(z)]^{COLR}$ factors.~~ Normally, this reference core condition is ~~HFP, ARO, EQXE~~. For simplicity, $A_{XY}(z)$ may be assumed to be ~~1.0. If, however, margin is needed for a Surveillance performed at conditions different from the reference core conditions, then the appropriate values for $A_{XY}(z)$ may be used. Sub factors of $A_{XY}(z)$ may also be determined and included in the COLR. These sub factors are $F_{PC}(z)$ and $F_{RC}(z)$. $F_{PC}(z)$ is a factor that adjusts the measured $F_{XY}^M(z)$ to the reference core power (typically RTP) if the Surveillance is performed at part power conditions. $F_{RC}(z)$ is a factor that adjusts the measured $F_{XY}^M(z)$ values to the reference rodded condition (typically ARO) if the surveillance condition includes insertion of the lead control bank. When these sub factors are used, $A_{XY}(z)$ is the product of $F_{PC}(z)$ and $F_{RC}(z)$.~~

[1.0815] is a factor that accounts for fuel manufacturing tolerances and measurement uncertainty.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each RAOC operating space.

~~REVIEWER'S NOTE~~

~~WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~

1.0, as this will typically result in an accurate $F_Q^W(z)$ Surveillance result for a Surveillance that is performed at or near the reference core condition, and an underestimation of the available margin to the F_Q limit for Surveillances that are performed at core conditions different from the reference condition. Alternatively, the $A_{XY}(z)$ function may be calculated using the NRC approved methodology in Reference 6.

Revised INSERT #1 for Bases B 3.2.1C

$[W(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[W(z)]^{COLR}$ functions are specified for each analyzed CAOC operating space (i.e., each unique combination of AFD band and Control Bank Insertion Limits). The $[W(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each CAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[W(z)]^{COLR}$. The $[W(z)]^{COLR}$ functions also account for the following effects: (1) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (2) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (3) the increase in radial peaking due to non-equilibrium xenon effects. The $[W(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at the Target Axial Offset core conditions. Surveillance specific $[W(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

~~$A_Q(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_Q^M(z)$ to the Target Axial Offset core conditions. For simplicity, $A_Q(z)$ may be assumed to be 1.0 when the surveillance is performed at the target AO. If, however, margin is needed for a Surveillance performed at conditions different from the Target AO core conditions, then the appropriate values for $A_Q(z)$ may be used.~~

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each CAOC operating space.

~~REVIEWER'S NOTE~~

~~WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.~~

$A_Q(z)$ is a function that adjusts the $F_Q^W(z)$ Surveillance for differences between the reference core condition assumed in generating the $[W(z)]^{COLR}$ function and the actual core condition that exists when the Surveillance is performed. Normally, this reference core condition is defined as the same core condition that is used to establish the target AO (i.e., the target axial flux difference at RTP) in LCO 3.2.3. For simplicity, $A_Q(z)$ can be assumed to be 1.0 when the $F_Q^W(z)$ Surveillance is performed at a core condition consistent with updating the target AO and when Control Bank D is not inserted below the axial elevation where the limiting F_Q margin is predicted to occur (as specified in the COLR). $A_Q(z)$ can also be assumed to be 1.0 if the $F_Q^W(z)$ Surveillance is not performed at conditions consistent with updating the target AO, and a Surveillance specific $[W(z)]^{COLR}$ function associated with performing the Surveillance at the applicable core condition is specified in the COLR. If the conditions specified in the COLR for assuming $A_Q(z)$=1.0 are not met and a Surveillance specific $[W(z)]^{COLR}$ function has not been specified, then the $A_Q(z)$ function is calculated using the NRC approved methodology in Reference 6.

ATTACHMENT 4

Revision to Section F.2.2.6 on Page F-2 of WCAP-17661, Revision 1

(Sample COLR Input for a CAOC Plant)

(3 pages including Attachment 4 cover page)

where:

$$F_Q^C(z) = F_Q^M(z) * 1.0815$$

$$P = \frac{THERMAL\ POWER}{RATED\ THERMAL\ POWER}$$

F.2.2.2:

$$F_Q^{RTP} = 2.50$$

F.2.2.3:

K(z) is provided in Figure F-2.

F.2.2.4:

$$F_Q^W(z) \le \frac{F_Q^{RTP}}{P} * K(z) \quad for\ P > 0.5$$

$$F_Q^W(z) \le \frac{F_Q^{RTP}}{0.5} * K(z) \quad for\ P \le 0.5$$

where:

$$F_Q^W(z) = F_Q^C(z) * \frac{[W(z)]^{COLR}}{P} * A_Q(z) * R_j$$

F.2.2.5: WCAP-17661

$[W(z)]^{COLR}$ values are provided in Tables F-1, F-2, and F-3 for COS1, COS2, and COS3, respectively.

F.2.2.6: if the conditions discussed below are met

can

The $A_Q(z)$ factor adjusts the surveillance to the Target AO conditions. $A_Q(z)$ ~~may~~ be assumed to be equal to 1.0 ~~or~~ may be determined for specific surveillance conditions using the approved methods listed in ~~TS 5.6.5~~. ~~If $A_Q(z)$ is assumed to be equal 1.0, the surveillance should be performed as close as possible to the Target AO.~~

INSERT 1

F.2.2.7:

The R_j penalty factors account for the potential decrease in transient F_Q margin between surveillances. The R_j factors for COS1, COS2, and COS3 are provided in Tables F-4, F-5, and F-6, respectively.

F.2.2.8:

INSERT 1

Specifically, $A_Q(z)$ can be assumed to be equal to 1.0 if the surveillance is performed at core conditions consistent with updating the measured Target AO and Control Bank D is not inserted below 200 steps withdrawn[1]. Alternatively, $A_Q(z)$ can be assumed to be equal 1.0 if a surveillance specific W(z) function is being used that is consistent with the core conditions of the surveillance.

[1] Reviewer's Note: The Control Bank D insertion requirement will be determined on a cycle specific basis, based on bounding the predicted limiting axial elevation for the $F_Q^W(z)$ margin. This single value can also be replaced with a table of Control Bank D insertion as a function of cycle burnup.

From: Holderbaum, Chad M.
Sent: Monday, April 30, 2018 11:02 AM
To: Andrachek, James D; Hone, Michael J.; Moorehead, John D.
Cc: Holderbaum, Chad M.
Subject: WCAP-17661 Draft SE
Attachments: Draft SE- PRWOG 17661 encrypted.docx

Importance: High

Draft SE attached.

-----Original Message-----
From: No-Reply@amrdec.army.mil [mailto:No-Reply@amrdec.army.mil]
Sent: Monday, April 30, 2018 10:49 AM
To: Holderbaum, Chad M.
Subject: AMRDEC Safe Access File Exchange Delivery Notice

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dFoJ3BKUNFOEPAf2mcrjGYcvYNn0Hc&m=k0X9wnZlgbUcKb7jPDdLnqYOTnxX9naTizEtsoHOBLk&s=wN_muNPdopmbOyJx apVmHaHdGGYj8vb9Ol_bgVl0te8&e=

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 24, 2018

Mr. W. Anthony Nowinowski, Program Manager
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

SUBJECT: DRAFT SAFETY EVALUATION FOR PRESSURIZED WATER REACTOR OWNERS GROUP TOPICAL REPORT WCAP-17661, "IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

Dear Mr. Nowinowski:

By letter dated January 2, 2014 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML14009A098), the Pressurized Water Reactors Owners Group (PWROG), submitted for Nuclear Regulatory Commission approval, Topical Report WCAP-17661, "Improved RAOC and CAOC F_Q Surveillance Requirements." The topical report (TR) was supplemented by letters dated September 13, 2016, and February 15, 2018 (ADAMS Package Accession Nos. ML16291A531 and ML18053A269, respectively). The TR provides the technical basis for updates to Technical Specification (TS) 3.2.1, "Heat Flux Hot Channel Factor," as presently contained in NUREG-1431, "Standard Technical Specifications – Westinghouse Plants" (ADAMS Accession Nos. ML12100A222 (Volume 1) and ML12100A228 (Volume 2)).

The NRC staff review determined that the revisions to the heat flux hot channel factor TS were acceptable. The revisions provide a more robust means for performing the $F_Q^W(Z)$ surveillance, a series of more restrictive operating spaces if the $F_Q^W(Z)$ LCO is not met, and a more clearly defined set of Surveillance Requirements and Required Actions. The TS changes also provide reasonable assurance that a core operated in accordance with these TS will remain within the power distribution limits assumed in the facility safety analyses.

Pursuant to Section 2.390 of Title 10 of the *Code of Federal Regulations* (10 CFR), we believe that the enclosed draft SE may contain proprietary information. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. Twenty working days are provided for you to comment on the proprietary aspects and provide any factual errors or clarity concerns contained in the SE. The final SE will be issued after making any necessary changes and a non-proprietary version will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

~~NOTICE: The enclosure transmitted herewith contains Proprietary Information. When separated from the enclosure, this transmittal document is decontrolled.~~

To facilitate the NRC staff's review of your comments, please provide a marked-up copy of the revised draft SE showing proposed changes and provide a summary table of the proposed changes.

If you have any questions, please contact Brian Benney at 301-415-2767.

Sincerely,

Dennis C. Morey, Chief
Licensing Processes Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 99902037

Enclosure:
Draft Safety Evaluation

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO PRESSURIZED WATER REACTOR OWNERS' GROUP

LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

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~~Proprietary information is enclosed in curly brackets and set in bold-face type.~~ ~~**{This sentence is an example of the proprietary designation.}**~~

~~Curly brackets were selected because square brackets denote other types of text in this document.~~

Enclosure

Contents

DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO PRESSURIZED WATER REACTOR OWNERS' GROUP

LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

1.0 INTRODUCTION

The Pressurized Water Reactor Owners Group (PWROG) submitted Topical Report (TR) WCAP-17661[1] for U.S. Nuclear Regulatory Commission (NRC) staff review by letter dated January 2, 2014 (Ref. 1). The TR provides the technical basis for updates to Technical Specification (TS) 3.2.1, "Heat Flux Hot Channel Factor," as presently contained in NUREG-1431, "Standard Technical Specifications – Westinghouse Plants" (Ref. 2). Specifically, the TR addresses (1) potential non-conservatisms in Required Action B.1 of TS 3.2.1B, which is applicable to Relaxed Axial Offset Control (RAOC) plants, and (2) "the sensitivity of the formulation of the associated Surveillance Requirement (SR) to the differences between the measured and predicted surveillance power shapes at both nominal and part power conditions" (Ref. 1). The TR was supplemented by letters dated September 13, 2016 (Ref. 3) and February 15, 2018 (Ref. 4). The supplements provided responses to the NRC staff requests for additional information (RAIs).

In addition to the changes described above, WCAP-17661 includes several other improvements to Versions B and C of TS 3.2.1. TS 3.2.1B is the version that is applicable to plants that have implemented the RAOC methodology, whereas TS 3.2.1C is the version that is applicable to plants that use the Constant Axial Offset Control (CAOC) – W(Z) methodology. Meanwhile, TS 3.2.1A, the version of the TS that is applicable to plants using the CAOC-F_{XY} methodology remains unchanged, and this TR does not apply to such plants.

All of the TS changes described and justified in WCAP-17661 are described in detail in Section 3.0 of this safety evaluation (SE).

1.1 BACKGROUND: POWER DISTRIBUTION TERMS

The TR relates to peaking factors that are used to describe the power distribution at Westinghouse Electric Company (Westinghouse)-designed plants. These factors, and the various functions, factors, and limits that are used to manipulate the peaking factors in order to ensure they provide appropriate margins for uncertainties and operational transients over a given surveillance interval, are summarized in Table 1, located in the appendix to this SE. The table first defines the peaking factors, then provides the limits, functions, and multipliers, and finally provides definitions for the various different versions of each peaking factor.

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[1] As noted in the citation for Reference 1, WCAP-17661 exists in both proprietary (WCAP-17661P) and publicly available (WCAP-17661NP) formats. This SE is applicable to both formats, and refers to the TR generally without the proprietary designator (i.e., WCAP-17661).

It is useful to refer to Table 1 alongside subsequent sections of this SE, in which the terms contained in the table are frequently used in discussing the algebraic formulations of the surveillance terms and operating limits.

1.2 PURPOSE OF TOPICAL REPORT

In 2009, Westinghouse identified a non-conservatism associated with the limiting conditions for operation (LCOs) and associated SRs for the Heat Flux Hot Channel Factor ($F_Q(Z)$) for Westinghouse nuclear power plants. Specifically, it was recognized that the Required Actions in NUREG-1431 (Ref. 2), in situations where the plant does not meet an F_Q limit, are not as conservative as previously understood.

Westinghouse issued Nuclear Safety Advisory Letter (NSAL) 09-5, "Relaxed Axial Offset Control F_Q Technical Specification Actions," to address the situation on an interim basis (Ref. 5). The NSAL required four specific actions, in addition to the current specific Required Actions contained in the plant-specific F_Q TSs, if it was determined that F_Q was not within the LCO limit following a surveillance performed at ≥ 75 percent rated thermal power (RTP). These actions are very conservative so that they envelop all plants.

The non-conservatism becomes apparent in plants using RAOC rather than CAOC. A key surveillance parameter, $F_Q^W(Z)$, is the product of analytical factors and surveillance measurements. The analytical factors are derived before each reload, and must assume a reference condition for the surveillance, even though the surveillance takes place after the plant returns to power, and hence, well after the analytical factors are derived. The initial surveillance condition is not necessarily the same as the reference condition, and this can lead to an inaccuracy that is non-conservative.

The PWROG submitted WCAP-17661 in order to develop a permanent resolution to the problem and define appropriate revisions to the standard TS (STS) related to the F_Q surveillance. The intent is to replace the temporary actions required by the NSAL in case F_Q is found outside the LCO limits with Required Actions that will assure that plant operation will remain bounded by the facility safety analyses. The PWROG submitted WCAP-17661 to the NRC, requesting approval in order to make subsequent changes to the STS, NUREG-1431. The specific TS that are proposed to be changed are TS 3.2.1B, Heat Flux Hot Channel Factor (F_Q (Z) (RAOC-W(Z) Methodology)) and TS 3.2.1C, Heat Flux Hot Channel Factor (F_Q (Z) (CAOC-W(Z) Methodology)).

1.3 SUMMARY OF CHANGES

The following discussion provides a brief summary of the changes set forth in WCAP-17661. A detailed discussion of each change is provided in Section 3.0 of this SE, and a summary of changes in tabular format is provided in Table 2, in the appendix.

1.3.1 Limiting Conditions for Operation (Unchanged)

The LCOs for TS 3.2.1B and 3.2.1C remain unchanged. The requirement, in both versions of the LCO, remains for $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, to remain within the limits specified in the core operating limits report (COLR). The approximations for these parameters, however, will change as discussed in the succeeding sections.

1.3.2 Core Operating Limits Report Content

Based on the discussion contained in the TR, the NRC staff determined that the typical COLR content[2] will change. As outlined below, the amount of the COLR content related to $F_Q^W(Z)$ will increase. Primarily, this increase stems from the following items, which will be newly included in the COLR:

1. The definition of new RAOC operating spaces (ROSs) or CAOC operating spaces (COSs),

2. The inclusion of a normalization factor $A_{XY}(Z)$ for RAOC, or $A_Q(Z)$ for CAOC[3],

3. The definition of a penalty factor, R_j, and

4. The inclusion of separate control rod insertion limits, transient functions, penalty factors, and axial flux difference (AFD) bands for the new ROSs and COSs.

The COLR will also include newly formulated, cycle-specific limits associated with implementing the proposed Required Actions to take in the event that completion of a SR indicates that an LCO is not met.

1.3.3 Surveillance Requirements

For RAOC plants, rather than formulating the $F_Q^W(Z)$ surveillance parameter by using a core-wide, three-dimensional surveillance to measure F_Q, the surveillance will now determine a synthesized F_Q using a planar F_{XY} surveillance and multiplying it by a reference axial power shape. The surveillance is repeated for each plane in the core, from 15- to 85-percent core height to determine a maximum to compare to the limit.[4] The philosophy of using multipliers to the measured value to provide margin for manufacturing tolerances, surveillance uncertainty, and operational transients over the following surveillance interval remains unchanged. However, the formulation of the transient function is modified.

In addition, some language contained in the SRs has been modified to add clarity, and minor changes to some surveillance frequencies have been proposed.

1.3.4 Required Actions

The Required Actions associated with both $F_Q^W(Z)$ and $F_Q^C(Z)$ have been modified. These modifications serve two primary purposes: (1) to provide more explicit limitations on thermal

---

[2] This list was formulated by reviewing a sample of COLRs submitted on several dockets. The content of a specific COLR varies from plant to plant, and not all plants may have the exact content listed here.

[3] As discussed in Section 4.1, the NRC staff determined that the use of such factors, when less than unity, was not acceptable.

[4] Per NUREG-1431, "The top and bottom 15-percent of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions" (Ref. 2, Volume 2, SR 3.2.1.2). Note that the top and bottom 15-percent exclusion zones are typical, however, the exclusion zone is established on a cycle specific basis to ensure that the limiting margin location is surveilled. Therefore, for a specific operating cycle, exclusion zones smaller than 15-percent may be specified.

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power and reactor trip setpoints in the condition that the SRs are not met, and (2) to accommodate the implementation of successively restrictive operating spaces in the event that the SRs are not met.

2.0 REGULATORY EVALUATION

The specification of and adherence to limits on F_Q ensures that the value of the initial total peaking factor assumed in the accident and transient analyses remains valid. As noted in NUREG-1431, the F_Q limits assumed in the emergency core cooling system (ECCS) performance evaluation are typically limiting relative to the F_Q limits assumed in safety analyses for other postulated accidents and anticipated operational occurrences. Even if the ECCS limits are less limiting than those determined by another safety analysis, specification of and adherence to the F_Q limits still ensures that facility operation remains bounded by the safety analyses.

The regulatory evaluation thus identifies performance requirements and design criteria contained within Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities." The applicable requirements related to the specific content of TSs, relative to the facility safety analysis, are also identified, including appropriate guidance for administratively controlling such specifications. Finally, Section 2.3 of this SE summarizes the way in which the regulatory requirements apply specifically to the reformulated TS for F_Q.

2.1 PERFORMANCE REQUIREMENTS AND DESIGN CRITERIA

The performance requirements and design criteria applicable to the power distribution assumed in the safety analysis are those that pertain to accident and transient analysis. Primarily these include the requirements contained in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," and General Design Criterion (GDC) 10, contained in Appendix A, "General Design Criteria for Nuclear Power Plants." Since the TS also prescribe appropriate remedial action to follow if TS limitations are not met, some additional GDCs relative to the reactor protection and reactivity control systems also apply, as listed below.

The requirements in 10 CFR 50.46 state, in part, that ECCS shall be designed such that an evaluation performed using an acceptable evaluation model demonstrates that acceptance criteria, set forth in 10 CFR 50.46(b), including peak cladding temperature, cladding oxidation, hydrogen generation, maintenance of coolable core geometry, and long-term cooling are met for a variety of hypothetical loss-of-coolant accidents (LOCAs), including the most severe hypothetical LOCA.

GDC 10, "Reactor Design," states as follows:

> The reactor and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

GDC 20, "Protection System Functions," states as follows:

> The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated

operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety.

GDC 26, "Reactivity Control System Redundancy and Capability," states as follows:

> Two independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions.

2.2 TECHNICAL SPECIFICATIONS

The requirements for TS are set forth in 10 CFR 50.36, "Technical Specifications." Specific categories of TS are provided in 10 CFR 50.36(c). These include LCOs and SRs. If an LCO is not met, the facility must be shut down, or other acceptable remedial action must be taken. SRs are intended to ensure that facility operation remains within the LCOs. NRC Generic Letter (GL) 88-16, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," established the NRC position that licensees could remove the cycle-specific values of certain operating limits from the TS and maintain them in a COLR, provided that certain requirements were met (Ref. 6).

Paragraph (c)(2) of 10 CFR 50.36 discusses LCOs, stating that such TSs are the lowest functional capability or performance levels of equipment required for safe operation of the facility. The requirements indicate that LCOs must be established for each item that meets one or more of four criteria. One of the criteria is a process variable, design feature, or operating restriction that is an initial condition of a design-basis accident (DBA) or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

Paragraph (c)(3) of 10 CFR 50.36 states:

> Surveillance requirements are requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the LCOs will be met.

The guidance contained in GL 88-16 provides a means by which the values of certain parameters could be determined and modified on a cycle-specific basis without prior NRC review and approval. In order to implement this guidance, licensees are required to do the following: (1) use NRC-approved methodology to determine the operating limits; (2) include a list, in the TS Administrative Controls section, of the references used to determine the operating limits; and (3) maintain the limits in a COLR, which must be submitted to the NRC for information.

2.3 DISCUSSION

The safety analyses required to establish that a facility will comply with the requirements of 10 CFR 50.46, and with GDC 10, require as input the peak fuel power and the power distribution. Since the peak power and the power distribution are initial conditions of DBA and transient analyses, facility operation must be controlled by LCOs that are established based on these parameters. Hence, Westinghouse pressurized water reactors (PWRs) have LCOs relative to F_Q. In accordance with 10 CFR 50.36(c)(2), the LCO is accompanied by SRs to ensure that the LCO is satisfied. At plants that have implemented GL 88-16, specific parameter values may be administratively controlled, and in such cases these parameters must be determined in accordance with NRC-approved methodology, and contained in the facility COLR.

If during performance of a SR F_Q is determined not to be within the limit then the LCO is not met, and the TS remedial actions must be followed to ensure that facility operation remains safe. These remedial actions are based on (1) restoring compliance with the LCO, and (2) adjusting the reactor protection system settings so that the functionality required by GDCs 20 and 26 is maintained.

The NRC staff evaluation of the modified TS contained in WCAP-17661 considered whether the modified TS are consistent with the regulatory requirements identified above. In particular, the NRC staff evaluated whether (1) the revised TS LCOs ensure that facility operation remains within the bounds established by the safety analysis, (2) the reformulated SRs ensure that facility operation meets the LCOs, and (3) the revised required actions and completion times, applicable if either or both of the LCOs are not met, are appropriate to ensure that compliance with the unmet LCOs is restored, and that facility operation remains safe.

3.0 DETAILED SUMMARY OF CHANGES

This section expands on the discussion provided in Section 1.3 of the SE.

3.1 IMPROVED METHODOLOGY TO DEFINE RAOC AND CAOC F_Q SURVEILLANCE

The current $F_Q(Z)$ surveillance relies on a combination of analytical factors and periodic measurements to provide assurance that core operation does not lead to unacceptable local power peaking. This works well for CAOC plants but for RAOC plants the approach is not as robust. Specifically, the problem is that prior to each reload when the analytical factors are calculated, there has to be a prediction of the axial power shape at the time of surveillance and this is usually not known.

To understand how the new methodology is expected to overcome this problem, consider how the following F_Q surveillance parameter is defined:

$$F_Q^W(Z) = W(Z)[F_Q\ (Z)]_{Surv}^M * U_F \qquad \textbf{(1)}$$

where *W(Z)* is an analytically derived factor and the $F_Q(Z)$ in the brackets is the measured value (*M*) at the time of the surveillance (*Surv*). An uncertainty factor U_F is also added to this equation to account for both instrument uncertainty and manufacturing uncertainty. $F_Q^W(Z)$ must be less than or equal to a limiting value found in the COLR. It is related to the $F_Q^C(Z)$ surveillance parameter important to monitor steady state operation:

$$F_Q^W(Z) = W(Z) *\ F_Q^C(Z) \qquad \textbf{(2)}$$

The analytically derived factor $W(Z)$ **{**

} is relative to a reference condition. It is calculated prior to operation of a cycle and found in the COLR for use during the surveillances.

$$\left\{ \qquad\qquad\qquad \right\} \qquad \textbf{(3)}$$

where **{**

}. The denominator is the predicted (*p*) steady state value at the reference (*ref*) core condition. The latter is typically at hot full power with all control rods out and equilibrium xenon, which are not necessarily the conditions at which the surveillance F_Q is measured.

If the reference condition in Equation (3) is identical to the surveillance value in Equation (1) then the surveillance is done correctly, but if it is not, an error can be introduced. The new methodology replaces the factors in Equation (1) with equivalent factors which do not have the

overt dependence that the reference and surveillance axial distributions are identical. The new surveillance parameter is derived in detail in WCAP-17661. It is[5]

$$F_Q^W(Z) = \frac{[T(Z)]^{COLR}}{P_{rel}^{ss}} A_{XY}(Z) * [F_{XY}\ (Z)]_{SURV}^{M} * U_F\ *\ R_j \qquad \textbf{(4)}$$

Equation (4) uses both new analytical factors and new surveillance factors. The equation also includes a new penalty factor R_j. In this equation *[T(Z)]^COLR* is the pre-calculated function

$$\{ \qquad\qquad\qquad \} \qquad \textbf{(5)}$$

where $[P(Z)]_{ref}^{p}$ is the relative axial power predicted at the reference condition. P_{rel}^{ss} is the relative power level (actual power divided by the RTP) at the time of the surveillance. An additional analytical factor A_{XY} is included in Equation (4) to account for differences between the reference and surveillance conditions:

$$\left\{ \qquad\qquad\qquad \right\} \qquad \textbf{(6)}$$

The proposed approach (Equation (4)) is made consistent by using the measured $F_{xy}(Z)$ rather than $F_Q(Z)$ as in Equation (1) or (2). There is also the same factor U_F as in Equation (1) to take into account uncertainties.

The penalty factor R_j for surveillance time point j is used to account for the expected decrease in margin due to non-equilibrium operation over the period of operation prior to the next performance of SR 3.2.1.2.

The above approach to redefine the surveillance parameter factors is not needed for CAOC plants. However, analogous changes are proposed to the surveillance equation for CAOC plants to adjust for differences in the reference and surveillance conditions, and to implement the same penalty R_j for any expected decrease in margin prior to performing the next surveillance. The result changes the CAOC surveillance parameter from that shown in Equation (2) to the following:

$$F_Q^W(Z) = \frac{[W(Z)]^{COLR}}{P_{rel}^{ss}} * A_Q(Z) * \left[F_Q(Z)\right]_{Surv}^{M} * U_F\ *\ R_j \qquad \textbf{(7)}$$

where the adjustment ratio is:

$$\left\{ \qquad\qquad\qquad \right\} \qquad \textbf{(8)}$$

[5] Only the situation for surveillance done above a relative power of 0.5 (i.e., 50-percent RTP) is considered herein. The situation below this power is an obvious extension and is given in WCAP-17661.

According to WCAP-17661, the usual case is that surveillances are performed at core conditions close to the conditions corresponding to the target axial offset measurement and hence, $A_Q(Z)$ will be very close to 1.0.

3.2 PROPOSED CHANGES TO TECHNICAL SPECIFICATIONS 3.2.1B AND 3.2.1C

The improved methodology for F_Q surveillance was used to define a number of changes to both RAOC and CAOC F_Q surveillance, i.e., both TS 3.2.1B and TS 3.2.1C are proposed to be revised. One obvious change is to substitute T(Z) for W(Z) in the title of TS 3.2.1B. A summary of the other proposed changes in each TS is given below and further summarized in Table 2.

3.2.1 Changes to NOTE and Required Actions for Condition A: $F_Q^C(Z)$ not Within Limit

Changes are considered for the NOTE to Condition A and for Required Actions A.2 and A.3. The Changes are the same for both RAOC and CAOC plants.

The NOTE for Condition A stated, "Required Action A.4 shall be completed whenever this Condition is entered." It is proposed to be changed as follows:

> Required Action A.4 shall be completed whenever this Condition is entered *prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.*

When $F_Q^C(Z)$ is not within limit, the Required Actions were defined as follows:

(1) Reduce thermal power ≥ 1% RTP within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$) prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The wordings in the Required Actions A.2 and A.3 which specify the magnitude of the setpoint reductions are proposed to be modified to account for the possibility that the limit for $F_Q^C(Z)$ is exceeded during a part-power surveillance.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) Reduce thermal power ≥ 1% RATED THERMAL POWER within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1* within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required action A.1* within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(Z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$ prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The Completion Times associated with these Required Actions were not revised.

With the proposed change, when the limit for $F_Q^C(Z)$ is exceeded, thermal power will be limited to less than the surveillance power level required by Required Action A.1. The corresponding setpoints will therefore reflect this new thermal power limit. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, then thermal power will be limited to ≤ 74 percent RTP. Consequently, the new wording will require setpoint reductions of ≥ 26 percent since this is the amount by which the thermal power is limited below the RTP. The current Required Action wording would only require a setpoint reduction of ≥ 1 percent. In other words, the current requirement did not account for surveillance conducted at reduced power.

3.2.2 Changes to the Required Actions and NOTE for Condition B: $F_Q^W(Z)$ not Within Limit

The Required Actions for Condition B are different for RAOC and CAOC plants. Both are proposed to be revised in the improved F_Q TSs.

3.2.2.1 Proposed changes for RAOC plants

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."

In addition, there was a NOTE with Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved F_Q TSs, pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be in the COLR with characterized transient factors (T(Z) functions) which, in conjunction with the radial peaking factors, may be used to quantify the margin and ensure compliance with the LCO for future non-equilibrium operation. An RAOC operating space is a unique combination of an AFD operating space envelope and control rod bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient F_Q margin, minimum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the reduction is included in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) *Implement a RAOC operating space specified in the COLR that restores* $F_Q^W(Z)$ *to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER and reduce AFD limits as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is changed to "Prior to increasing THERMAL POWER above the *limit of Required Action B.2.1.*"

The NOTE in Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "*Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1.*"

3.2.2.2 Proposed changes for CAOC plants

The changes to the TS for CAOC plants (TS 3.2.1C) are similar to those for the TS of RAOC plants (TS 3.2.1B). However, the current requirements for these two types of plants are slightly different.

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that $F_Q^W(Z)$ exceeds limit (Required Action B.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the limit of Required Action B.1."

In addition, there was a NOTE with Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved CAOC F_Q TSs, a new Required Action B.1.1 is proposed which requires implementation of a new CAOC operating space, specified in the COLR, which restores $F_Q^W(Z)$ to within its limits. A CAOC operating space is a unique combination of CAOC AFD band limits and control rod bank insertion limits. A more restrictive CAOC operating space limits the range of possible non-equilibrium power shapes more than the current CAOC operating space through a smaller AFD band and/or shallower control rod insertion limits. The smaller CAOC operating space results in more transient F_Q margin. Alternatively, instead of implementing a more restrictive CAOC operating space, thermal power may be limited to some maximum value as specified in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) *Implement a CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is "Prior to increasing THERMAL POWER above the limit of Required Action B.2.1."

In addition the NOTE in Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed *prior to increasing the THERMAL POWER above the limit of Required Action B.2.1.*"

3.2.3 <u>Changes to Surveillance Requirements</u>

The SRs are modified by a NOTE. The NOTE states the following, "During power escalation at the beginning of each cycle, thermal power may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."

The NOTE for the SR is proposed for elimination because it was considered to have been a source of confusion and can be interpreted differently by different utilities implementing the requirement.

3.2.4 <u>Changes to Surveillance Requirements for $F_Q^C(Z)$: SR 3.2.1.1</u>

The current SRs for $F_Q^C(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.1 requires verification that $F_Q^C(Z)$ is within its limits and it must be verified at the specified Frequency:

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 effective full power days (EFPD) thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In the improved F_Q TS, the second frequency is proposed to be revised to require verification within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period to perform the verification.

3.2.5 Changes to Surveillance Requirements for $F_Q^W(Z)$: SR 3.2.1.2

The current SRs for $F_Q^W(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.2 requires verification that $F_Q^W(Z)$ is within its limits and it must be verified at the specified Frequency (same as $F_Q^C(Z)$):

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 EFPD thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In addition, there is a NOTE which modifies the SR as follows:

> "If measurements indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$:
>
> (1) Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or
>
> (2) Repeat SR 3.2.1.2 once per 7 EFPD until either a., above, is met, or two successive flux maps indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has not increased."

The revised SR 3.2.1.2 modifies the first and second Frequency (items (1) and (2) above) and eliminates the NOTE.

The first Frequency is modified to be conducted following each refueling within [24] hours after achieving equilibrium conditions after thermal power exceeds 75 percent RTP. This change is justified based on multiple reasons:

- Initial startups are not expected to result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit since initial startups are slow and are tightly controlled due to startup ramp rate limitations and fuel conditioning requirements.

- Core power distribution measurements taken at low power (<50 percent RTP) to confirm that the core is loaded properly will provide ample indications that the core is operating consistent with the expectations.

- Surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75 percent RTP will ensure that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium conditions could be limiting.

- Power levels of ≤ 75 percent RTP are non-limiting for minimum transient $F_Q^W(Z)$ margin. Conducting surveillance within 24 hours after achieving equilibrium conditions after thermal power exceeds 75 percent RTP will assure verification prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

The second frequency is modified in the same way as SR 3.2.1.1 discussed earlier. It is proposed to require verification of $F_Q^W(Z)$ within 24 hours (instead of 12 hours) after achieving the equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period in which to confirm that $F_Q^W(Z)$ is within its limits given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The NOTE is eliminated, but the application of the penalty factor remains because it is in the $F_Q^W(Z)$ formulation in the improved methodology for F_Q Surveillance. The required penalty factor, referred to as R_j in the new formulation, will be included in the COLR and will be tied to a predicted decrease in the actual transient F_Q margin in the upcoming time period prior to the next performance of SR 3.2.1.2 rather than a measured increase in the value of $F_Q^C(Z)$/K(Z) over the previous time period. When the transient F_Q margin is predicted to increase, the COLR will indicate an R_j factor of 1.0 (i.e., no penalty). When the margin is predicted to decrease, the COLR will indicate an appropriate R_j factor based on the predicted margin trends.

3.3 ATTRIBUTES AND IMPROVEMENTS OF REVISED F_Q SURVEILLANCE METHOD

The following seven attributes/improvements were the response to RAI 13b, which asked for a discussion of the changes in the TSs and their relation to the improved methodology. This list provides a good summary of what is being attempted.

(1) The formulation for determining the measured transient $F_Q^W(Z)$ in RAOC plants has been revised to be less sensitive to the ability to predict the actual steady state axial power shape conditions where the surveillances are performed.

This is related to the use of the new T(Z) surveillance factor, which no longer includes the steady state axial power shape in the denominator, relative to the original W(Z) factor.

(2) Correction factors have been defined for the new F_Q surveillance equations which correct the results for any remaining errors associated with the actual plant conditions where the surveillance is performed, which may differ from the

predicted surveillance condition.[6] These factors are the $A_{XY}(Z)$ factors for RAOC plants and the $A_Q(Z)$ factors for CAOC plants, which have been added to the respective equations used to perform the $F_Q^W(Z)$ surveillance (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661). Two methods have been presented for representing the $A_{XY}(Z)$ and $A_Q(Z)$ factors. This includes the very simple assumption of unity for the factors, and a rigorous calculation of the factors at the specific conditions of each surveillance.

(3) The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillances at part power conditions. This is done by moving the relative power term of the condition where the surveillance is performed out of the surveillance factors (i.e., T(Z) and W(Z)) and into the actual surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P). For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at the 50 percent RTP power level.

(4) Required Actions for cases where $F_Q^W(Z)$ exceeds the F_Q limit have been more rigorously defined and eliminate all reliance on "rules of thumb" that may not be strictly applicable in all situations. This is implemented through the possible application of new RAOC or CAOC operating spaces, or through the pre-defined limitations on power and AFD provided in the COLR, which are rigorously calculated using the standard NRC-approved analysis methods. These changes ensure that corrective actions taken in the rare circumstances when $F_Q^W(Z)$ exceeds the F_Q limit will be effective at restoring the necessary margin.

(5) The application of the burnup dependent penalty factor (R_j) to account for predicted decreases in the transient $F_Q^W(Z)$ margin during the next 31 EFPDs has been modified to apply to all surveillances, independent of the trends in measured $F_Q^C(Z)$ margin. This is implemented by incorporating R_j into the surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661) and eliminating the conditional application of the penalty factor in the TS surveillances. This improvement corrects cases where the measured trend in $F_Q^C(Z)$ margin from the previous 31 EFPDs may be increasing, but the trend in $F_Q^W(Z)$ margin is decreasing due to changes in the surveillance factor data.

(6) Requirements to perform SRs 3.2.1.1 and 3.2.1.2 have been clarified in cases where $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed the F_Q limit. In any case where one or both parameters exceed the limit, both surveillances are required to be performed by the TS's Required Action.

(7) The F_Q surveillance TSs have been revised to rely on $F_Q^C(Z)$ surveillances during the initial power ascension after a refueling to demonstrate that continued power ascension is justified. The first $F_Q^W(Z)$ surveillance is not specifically required to be performed until 24 hours after the plant reaches equilibrium conditions at a power level greater than 75 percent RTP. This change recognizes the technical

[6] As discussed in Section 4.1, the NRC staff determined that the use of such factors, when less than unity, was not acceptable.

fact that the surveillance factors needed to perform an accurate $F_Q^W(Z)$ surveillance at very low THERMAL POWER levels are difficult to accurately calculate in advance of the surveillance, and that the most accurate $F_Q^W(Z)$ surveillances will be obtained from equilibrium conditions at greater than 75 percent RTP. The change is justified by the fact that the $F_Q^C(Z)$ surveillances confirm the core is behaving as predicted, and the initial power ascension after a refueling outage is performed in a slow, controlled manner, until the fuel is conditioned. The first $F_Q^W(Z)$ surveillance that is performed following a refueling justifies operation at 100 percent RTP over the next 31 EFPDs, under potential transient operation.

4.0 TECHNICAL EVALUATION

4.1 IMPROVED F_Q SURVEILLANCE FORMULATION

The rationale for the improved surveillance formulation was discussed in Section 3.1 and the new approach to defining $F_Q^W(Z)$ was summarized therein. Equation (4) represents the new formulation for RAOC plants and Equation (7) for CAOC plants. The derivation of these formulas in WCAP-17661 has been reviewed and found to be rigorous with the exception of the penalty factor R_j which is added to take into account trends with burnup. In the following each of the important factors in Equation (4) for RAOC plants are considered. The evaluation for CAOC plants follows along similar lines.

The T(Z) factor is obtained as it always has been for the equivalent W(Z) {

}.

The PWROG proposed to introduce the $A_{XY}(Z)$ and $A_Q(Z)$ factors defined in Equations (6) and (8), respectively, to adjust for a change in radial peaking factor due to difference in power level and control rod insertion relative to the reference core condition. In practice, the $A_{XY}(Z)$ and $A_Q(Z)$ factors allow for a slight adjustment, usually a reduction, in the calculated $F_Q^W(Z)$, when the $F_Q^W(Z)$ surveillance is conducted {
}. This factor is evaluated in detail in Section 4.1.1 of this SE.

The use of the measured $F_{XY}(Z)$ rather than $F_Q(Z)$ is an important part of the new RAOC formalism. Examples of measurements from different reactors are shown in WCAP-17661 and although measurement of $F_{XY}(Z)$ can be problematic in planes where grids reside, this is not an issue, because grid plane regions are excluded from surveillance as noted below. Section 4.4 of WCAP-17661 notes that the regions where there are measurement exclusions continue to be:

- Lower core region, generally[7] from 0 percent to 15 percent inclusive
- Upper core region, generally[7] from 85 percent to 100 percent inclusive
- Grid plane regions, ±2 percent inclusive
- Core plane regions, within ±2 percent of the bank demand position of the control banks

The use of the uncertainty factor U_F to account for both instrumentation and manufacturing uncertainties was questioned (RAI No. 4) as it was not clear why a manufacturing uncertainty was needed. The RAI also questioned how the uncertainty in T(Z) was taken into account. The response to the RAI explains that the uncertainties used are conservative. The manufacturing (or engineering) uncertainty was originally introduced because the "measured" $F_Q(Z)$ in the formulation is a pin (i.e., fuel rod) power whereas the actual measurement is a fuel assembly power. The manufacturing uncertainty is needed to account for pin-to-assembly factors[8] that compensate for this difference. Since the measurement already accounts for actual

[7] Per Footnote 4 on Page 3, the plant- or cycle-specific exclusion regions may be different.
[8] As noted in the RAI response, these pin-to-assembly factors account for the fact that the analytically derived pin factors are based on nominal design characteristics such as pellet enrichment, density, and

as-manufactured conditions, this is not important. Furthermore, since the definition of the T(Z) factor is based on bounding calculations, it is not necessary to introduce additional uncertainty for this factor. Hence, it is concluded that the approach to uncertainty in the improved methodology is sufficiently conservative.

The last factor in Equation (4) is a penalty that Westinghouse is suggesting and is related to the elimination of the NOTE for SR 3.2.1.2. The NOTE (see also Section 4.4) required certain actions take place when the maximum over Z of $F_Q^C(Z)$/K(Z)[9] increased relative to the previous surveillance. The concern at the introduction of this requirement was deviations between measured and predicted steady state power shapes due to integral fuel burnable absorber-induced power shift (also known as axial offset deviation, AOD) or crud induced power shift (CIPS) both of which occur slowly over time. WCAP-17661 explains how AOD has been resolved so that fewer cores now experience it and the instances of AOD are less severe.

CIPS is explained in the report and in the response to RAI No. 6. Like AOD, it is less of a problem than it once was. "Furthermore, CIPS develops slowly and has a characteristic [delta axial offset] signature making it relatively easy to detect." Hence, Westinghouse has proposed that, should CIPS occur, the effect on transient F_Q margin can be addressed in a timely fashion (with modifications to core models) and there is no need for the generic penalty as expressed in the NOTE for SR 3.2.1.2. There are several reasons specified by Westinghouse as to why this approach is reasonable and this review concurs with that reasoning.

The penalty that is proposed to be added (R_j) is to take care of downward trends in the F_Q margin that might be possible due not to anomalies like CIPS but rather to ordinary changes caused by cycle depletion. Essentially the penalty added at the surveillance point j is related to the ratio of the $F_Q^W(Z')$ expected at the next surveillance point in the cycle (i.e., point j+1) to the $F_Q^W(Z')$ at point j, where the prime indicates that it is at the elevation where the margin to the limit is smallest. This calculation is done prior to the start of the cycle and the R_j are to be found in the COLR. The minimum value that can be used is 1.0. This approach is reasonable and further justifies the elimination of the NOTE in SR 3.2.1.2.

CAOC plants will have the option of using Equation (7) to define the surveillance parameter. The major change is the introduction of the $A_Q(Z)$ factor. This factor is evaluated alongside $A_{XY}(Z)$ in Section 4.1.1.

4.1.1 <u>Evaluation of A_{XY} and A_Q</u>

WCAP-17661 proposes to implement, in the $F_Q^W(Z)$ surveillance formulation, new factors A_{XY} and A_Q for RAOC and CAOC W(Z) surveillances, respectively. This factor is intended to normalize the T(Z) function used in the surveillance to the power distribution conditions present at the time of surveillance. The present evaluation is written based on the PWROG response to RAI 15, which included proposed revisions to WCAP-17661. The introduction to RAI 15 provides a succinct explanation of the purpose and derivation of the A factors.

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burnable absorber loading. The engineering uncertainty addresses the effects of variations in the as-built fuel pellet from such nominal values.

[9] K(Z) is a function that defines the axial dependence of the acceptable value of F_Q.

WCAP-17661, as revised, sets forth two methods for the A_{XY} and A_Q factors. Method 1 is to assume that it is always unity; in other words, surveillances would be performed without correcting for possible deviations from the reference condition, for which the T(Z) functions are determined. Method 2 is to perform on-line calculations.

Several considerations justify an allowance to keep the RAOC surveillance uncorrected. First among these is the fact that the vast majority of surveillances are conducted in a Hot Full Power (HFP), All Rods Out configuration such that there would be little deviation from the reference condition. Stated differently, in most cases, the A_{XY} factor would seldom deviate from unity, and deviations are usually expected to be minor. Second, the existing methodology does not include this correction. Third, PWROG provided, in response to RAI 15.e, several tables for a demonstration plant with several successive surveillances completed slightly above 80-percent RTP, with 14-percent D-bank control rod insertion. These tables show that the A_{XY} factor removes a small amount of conservatism from the uncorrected surveillance, meaning that, in these conditions, a unity-value A_{XY} is conservative. The PWROG also provided a table illustrating what an A_{XY} correction would be if the plant were perturbed to a lower power level, close to 50-percent RTP, where the A_{XY} correction at the limiting margin elevation corrects an approximately { } of actual F_Q margin. The data provide an indication that the A_{XY} correction is usually minor, and that it increases in magnitude as the core begins to deviate more from the reference condition. Based on the PWROG demonstration that the A_{XY} factor is generally a minor correction to the $F_Q^W(Z)$ RAOC surveillance, the NRC staff determined that Method 1 for A_{XY} an acceptable way to correct for off-reference conditions.

If the A_{XY} or A_Q factor is implemented using Method 2, it will be calculated using the methods listed in the response to RAI 15.c, and subject to the constraints discussed in the response to RAIs 15.b and 15.d. The response to 15.b includes references to the currently acceptable TRs describing methods for calculating the A_{XY} and A_Q factors. Additional, newer methods may also be used, provided they are specifically found to be acceptable by the NRC staff for doing so.

A_{XY} is, by definition, a ratio of {

} As such, the response to RAI 15.b describes several items that may cause discrepancies. The discrepancies arise because the T(Z) function is based on the original core design, whereas the A_{XY} numerator will reflect properties of the actual core, such as actual inventory of reconstituted fuel assemblies and the use of an actual previous cycle shutdown burnup instead of the burnup window used in the original design. The response to RAI 15.b also indicates that the same discrepancies would be included in the A_{XY} denominator, or the $F_{XY}(Z)$ function for the surveillance condition, meaning that the ratio remains valid despite the difference between the as-designed and as-operated conditions. In addition, the PWROG stated that the depletion calculations for the as-operated conditions would be performed in the same manner as the original nuclear design model. These considerations

ensure that the A_{XY} factor is a valid proportion to use when scaling the T(Z) function to return values appropriate for the surveillance conditions. Limitation 2 in Chapter 5 of this SE addresses requirements to use NRC-approved core design or surveillance methods to calculate the A_{XY}, and to perform the calculations consistent with the original core design model.

In large part, the A_Q factor operates in CAOC – T(Z) surveillance the same as A_{XY} does in RAOC surveillance, with a noteworthy difference. The A_Q factor was more likely to be greater than unity by a significant amount, particularly at rodded core elevations. Therefore, in the response to RAI 15.a, PWROG proposed two additional constraints on the use of a unity value A_Q, i.e., Method 1, to complete off-nominal surveillance: such surveillance is precluded if the current axial offset is more than ±1.5-percent of the target value, or if Control Bank D is inserted to the elevation of anticipated limiting $F_Q^W(Z)$ margin. Subject to this constraint, which is also reflected in Limitation 2 in Chapter 5 of this SE, the NRC staff determined that the use of methods 1 and 2 to calculate the A_Q factor for CAOC-W(Z) surveillance is acceptable, as the constraints will ensure that an explicitly calculated A_Q factor will be used when off-reference conditions would result in an $F_Q^W(z)$ surveillance that is unlikely to be sufficiently conservative.

4.1.2 Conclusion Regarding Improved Surveillance Formulation

In summary, the new approach for the surveillance parameter $F_Q^W(Z)$ for both RAOC and CAOC plants is valid and eliminates a non-conservatism in the previous approach for RAOC plants. Thus, the revised $F_Q^W(Z)$ surveillance provides improved assurance that an implementing facility will be operated within the initial conditions assumed in the safety analyses, consistent with the requirements set forth in 10 CFR 50.36(c)(3). It is therefore acceptable as part of the surveillance methodology.

4.2 REVISIONS TO REQUIREMENTS UNDER CONDITION A OF TS 3.2.1B AND 3.2.1C

This change[10] proposes to revise the setpoint reductions that are required when $F_Q^C(Z)$ is not within limits. Specifically, Required Actions A.2 and A.3 will be revised replacing "1 percent for each 1 percent $F_Q^C(Z)$ exceeds limits" with "1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."

The proposed new wording will require greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(Z)$ exceeds its limits. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, thermal power will be limited to ≤ 74 percent RTP. This new wording will require setpoint reductions of ≥ 26 percent since this is the amount by which the thermal power is limited below the RTP. In other words, both Neutron Flux – High trip setpoints and Overpower ΔT trip setpoints will require setpoint reductions of ≥ 26 percent. This is different from the current wording which requires a setpoint reduction of ≥ 1 percent.

The current wording implicitly assumed that the surveillance is always performed at full power. The revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance and appropriately defines the setpoint reductions.

[10] See Table 2 for a list of all changes.

The proposed revision to the Required Actions A.2 and A.3 addresses an issue with the actions for surveillance conducted at part-power. These changes will require an appropriate conservative reduction of the setpoints assuring that the limits on $F_Q^C(Z)$ assumed in the accident analyses remain valid. With the change, the requirements are appropriately worded for implementation since they are connected to the power level reductions defined in Required Action A.1.

The NOTE to Condition A is revised. It previously stated that "Required Action A.4 shall be completed whenever this Condition is entered." This NOTE was considered confusing, given the changes being proposed for SR 3.2.1.1 and 3.2.1.2. The revised NOTE states: "Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling." This revision makes the NOTE consistent with the changes in Required Actions and SRs, and it resolves the issue described above by making the NOTE more explicit.

These changes are not expected to cause any new accident or increase the likelihood of considered accidents. Rather, the changes are expected to reduce the consequence of accidents by assuring that $F_Q^C(Z)$ remains within the bounds assumed in the accident analyses. The proposed remedial actions are conservative compared to the current actions and can contribute to an improved margin of safety. Based on these considerations, the NRC staff determined that the proposed revisions are acceptable, insofar as they are consistent with the requirements established in 10 CFR 50.36(c)(2) for remedial actions, which may be established for conditions when an LCO is not met.

4.3 REVISIONS TO REQUIREMENTS UNDER CONDITION B OF TS 3.2.1B AND 3.2.1C

The newly added Required Actions replace prior actions requiring reduction of the AFD limits by one percent for each percent that $F_Q^W(Z)$ exceeded its limits, followed by a requirement to reduce thermal power level if the former Required Action does not restore adequate $F_Q^W(Z)$ margin. Administratively, licensees have eliminated the AFD required action and are presently required to reduce power if $F_Q^W(Z)$ exceeds its limits, in response to NSAL 09-5.

The revisions to the Required Actions associated with $F_Q^W(Z)$ exceeding its limits address the concern that the AFD reductions currently prescribed by TS are not sufficiently conservative to restore adequate margin to the heat flux hot channel factor. The existing TS Required Actions are based on assumptions that (1) the $F_Q^W(Z)$ violation occurs when the axial peak is outside the core mid-plane, and (2) constraining the power peaking in the core to its axial mid-plane region will restore the necessary margin. The PWROG notes that $F_Q^W(Z)$ violations are uncommon, and that when they occur, they do so more frequently outside the core mid-plane. However, the existing Required Action does not restore margin if the $F_Q^W(Z)$ violation occurs near the core mid-plane. To resolve the issue, the TR introduces a ROS or COS, depending on the power maneuvering control strategy, that can constrain AFD limits as before, but also introduces new T(Z) functions and possibly control rod insertion limits to further constrain maneuvering capability and restore the necessary margin. Rather than being based on assumptions that constraining the AFD limits yields the necessary margin, the new operating spaces are based on maneuvering analyses.

4.3.1 Required Actions B.1.1 and B.1.2; Deletion of NOTE Requiring SRs 3.2.1.1 and 3.2.1.2 Whenever Condition B is Entered

A new Required Action B.1.1 was included, which requires licensees to "Implement an RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits" whenever $F_Q^W(Z)$ is determined to be not within the limits. Based on the NRC staff review, PWROG also proposed to add the associated Required Action B.1.2, for instances in which the implementation of a new operating space requires control rod motion. It states "Perform SR 3.2.1.1 and SR 3.2.1.2 [verification, respectively, that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits] if control rod motion is required to comply with the new operating space."

An ROS or COS is a unique combination of AFD limits and control bank insertion limits. The operating spaces are pre-analyzed using the approved methodology and included in the COLR. The number of operating spaces that will be included in the COLR will be determined by the utility in conjunction with the core designer. WCAP-17661 presents example calculations providing the thermal power limit and the required margin reductions for different $F_Q^W(Z)$ margin improvements for a RAOC plant (Table 6-10 for ROS) and thermal power limits for different $F_Q^W(Z)$ margin improvements for a CAOC plant (Table 9-7 for COS). For the RAOC plants, in the improved methodology the margin improvement can be confirmed using the T(Z) factors. Previously, it was presumed that the AFD limits would provide the necessary margin improvement.

As documented in the submitted TR, PWROG proposed to delete the NOTE in Condition B, which required the performance of SR 3.2.1.1 and SR 3.2.1.2 whenever the Condition was entered. This NOTE required verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. The deletion of this NOTE was the subject of Topics (a) and (c) under RAI 5, which sought to address the following issues:

- The use of a different operating space to gain margin improvement was considered an appropriate application of the new methodology presented. However, the NRC staff determined that situations may occur where a different rod insertion limit may be needed associated with some control rod movement. Withdrawal of a control rod could potentially increase the $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values (RAI 5a).

- Inclusion of the requirements to perform SR 3.2.1.1 and SR 3.2.1.2 may be necessary to assure that the changes in $F_Q^C(Z)$ and $F_Q^W(Z)$ remain acceptable assuring that the margin is being maintained (RAI 5c).

In responding to this RAI, PWROG agreed to modify the proposed Required Actions for Condition B of TS 3.2.1B and 3.2.1.C. Specifically, to address the above issues, PWROG agreed to add Required Action B.1.2, with a Completion Time of 72 hours. This new Required Action will require the completion of SRs 3.2.1.1 and 3.2.1.2 in the event that implementation of a new operating space results in the need to move the control rods to comply with a new rod insertion limit.

Completion of Required Action B.1, as originally proposed, may have resulted in a need to move the control rods. The measured $F_{xy}(Z)$ peak can occur adjacent to or in an assembly containing an inserted control rod and the withdrawal of the control rod could potentially increase the resulting $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values. Also, a revision to the allowed AFD

band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion in order to obtain and maintain the AFD within the allowed operating band.

With the addition of Required Action B.1.2 (the current Required Action B.1 becomes B.1.1) to perform SR 3.2.1.1 and 3.2.1.2 will provide assurance that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits or appropriate actions are taken. Performing these surveillances will also provide the operators assurance that the margin is being maintained. A 72-hour completion time is provided to ensure that the plant has time to restore equilibrium conditions in the event that control rod motions result in transient conditions.

In Topic (b) of RAI 5, the NRC staff determined that, to remain in the operating space defined by Required Action B.1, operators would need to have a clear understanding that the margin improvement is being maintained. Additional information for the operator may be needed to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary. The NRC staff requested that PWROG justify why a tabular presentation of the margin improvement as a function of the axial position or some other scheme in the COLR would not be required. In its response, PWROG stated that the margin can be determined by applying the new surveillance factors associated with the revised operating space to the power distribution measurement. Additionally, the PWROG noted that $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances would now be required in the event that implementation of a new operating space requires control rod motion. Thus, PWROG stated that performance of the SRs would provide the necessary margin confirmation. The NRC staff agrees with the PWROG response, since the concern was related to the implementation of new operating spaces in conjunction with control rod motion, which would require performance of new surveillances.

Topic (d) of RAI 5 addresses the actions that will be taken by the operators to remedy potential violations of the newly implemented operating space associated with Required Action B.1. The PWROG identified other TS Required Actions and SRs that would apply in such a situation, particularly with regard to control rod insertion limits and position. Because the potential for violation of the core operating limit parameters for an operating space can be addressed through existing TS Required Actions and SRs, the NRC staff determined that PWROG addressed the concern indicated in RAI 5d acceptably.

The improved methodology allows for the use of new operating spaces, as defined in the COLR. The addition of Required Action B.1.2 assures that for situations involving control rod movement surveillance will be conducted to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits. Based on the review described above, the NRC staff determined that the proposed Required Actions B.1 are acceptable.

4.3.2 Required Action B.2 and Limitation on Thermal Power

The improved TSs define a new Required Action B.2 which includes four actions (B.2.1, B.2.2, B.2.3, and B.2.4). If the RAOC or CAOC operating spaces defined in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Actions B.2 are entered. The actions involve reducing the thermal power to less than the thermal power specified in the COLR along with reduction of the setpoints. For more explicit presentation of the changes and associated justifications, see Table 2.

The issues addressed in the review of these changes related to the change of the thermal power level. As noted in WCAP-17661-P, the reductions in the thermal power levels evaluated and included in the COLR will be limited to three or less. An individual utility may opt for additional evaluation levels. If the required margin improvement exceeds the level of pre-analyzed thermal power limits, then the option is to limit the thermal power to < 50 percent RTP. The 50 percent RTP applies to all Westinghouse plants and no plant-specific evaluations are involved. However, in response to RAI 7, PWROG stated that the 50 percent value is consistent with the required power reduction associated with other power distribution surveillances (e.g., $F^N_{\Delta H}$), and agreed to add paragraphs addressing this scenario in the BASES.

The need to limit thermal power to < 50 percent RTP is expected to be a rare occurrence. However, such a situation may indicate a serious core anomaly and is a useful discussion in the TS BASES for understanding of the operating personnel. Since the 50 percent value is consistent with the power reduction associated with other peaking factor surveillances the NRC staff finds the proposed Required Action B.2 acceptable for the purposes of this TR.

The final required THERMAL POWER limit provided in the COLR input supporting Required Actions B.2 for each ROS or COS must be < 50 percent RTP. Even though the final power reduction amount is fixed, it is appropriate for inclusion in the COLR and not the TS, because the required amount of margin improvement at which this power reduction becomes necessary may vary from cycle to cycle. This is a limitation on the NRC staff approval of the TR, as discussed in Section 5.3 of this SE.

4.4 REMOVAL OF NOTES FOR F_Q SURVEILLANCE

Two notes in the SRs are proposed to be removed. The first note, applied to both SR 3.2.1.1 and 3.2.1.2, required obtaining the power distribution map for measuring $F_Q^C(Z)$ and $F_Q^W(Z)$ in equilibrium conditions during power escalation at the beginning of each cycle[11]. The second NOTE applies to SR 3.2.1.2 and requires multiplication of $F_Q^W(Z)$ by a factor and increased surveillance under certain conditions.

The first NOTE has been a source of confusion and was interpreted differently by various utilities. From section 3.2.4 of the topical report it appears that it was understood that a determination of $F_Q^C(Z)$ had to be obtained prior to exceeding 75 percent RTP. It is also considered that equilibrium conditions are not necessary for obtaining the power distribution map. The removal of the first NOTE removes any requirement for obtaining equilibrium conditions during the first power distribution map measuring $F_Q^C(Z)$. $F_Q^C(Z)$ is required to be verified after each refueling prior to exceeding 75 percent RTP in the first part of the frequency. The need for requirements for plant condition in the TS instead of the current NOTE was considered.

In consideration of the removal of the first NOTE, the first Frequency for SR 3.2.1.1 no longer includes a definition of the applicable plant condition. However, *equilibrium conditions* are defined for other surveillances. Given that *equilibrium conditions* are defined for the conduct of

[11] The first note stated, "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which [*sic*] a power distribution map is obtained."

surveillance, the NRC staff determined that a definition of *equilibrium condition* should be retained in the BASES discussion. The proposed change to the Bases associated with the SRs, to remove the definition of the *equilibrium condition*, can lead to confusion in implementing the surveillance and using the surveillance results. In its response to RAI 9, PWROG proposed define *equilibrium conditions*, for the purposes of SRs 3.2.1.1 and 3.2.1.2, as "...achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance." This definition was added to the BASES for both SRs. Since PWROG agreed to define the plant condition in the BASES, the NRC staff determined that the disposition regarding the plant condition for these surveillances was acceptable.

The effect of the removal of the first NOTE on SR 3.2.1.2 is that $F_Q^W(Z)$ will not be required to be determined until after equilibrium conditions are achieved after exceeding 75 percent RTP instead of before exceeding 75 percent RTP following a refueling outage as currently specified. For further detail regarding the change to the time the first $F_Q^W(Z)$ surveillance is required, refer to Item 7 in Section 3.3, and to Section 4.7, of this SE.

The second NOTE defined the penalty factor for $F_Q^W(Z)$. In the improved methodology, the penalty factor is embedded in the methodology and a separate penalty factor is not applicable. In addition, it is understood that an increasing trend in $F_Q^W(Z)$ measurement is not indicative of future margin trends and accordingly, increased surveillance based on an increasing trend may not be desired. Additional review considerations regarding the deletion of this NOTE appear in Section 4.6 of this SE.

Based on the considerations discussed above, the NRC staff determined that the proposed deletion of the NOTEs associated with F_Q surveillance was acceptable. In summary, the deletion of the first note will eliminate confusion and inconsistency among implementing licensees, the *equilibrium condition* required for the surveillances will be defined in the BASES, and the penalty factor associated with the second NOTE is now embedded in the methodology. The NRC staff also notes that revisions made to the NOTES in Condition A and Required Action B.2 clarify some of the conditions under which SRs 3.2.1.1 and 3.2.1.2 are necessary, further obviating the need for these NOTES.

4.5 REVISION OF SECOND SURVEILLANCE FREQUENCY FOR SRS 3.2.1.1 AND 3.2.1.2

Verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits (SR 3.2.1.1 and SR 3.2.1.2) includes a second requirement in the Frequency column of "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." This requirement assures verification of the F_Q limits whenever a significant increase of thermal power level has occurred.

The increase in the time interval for completing the required surveillance from 12 to 24 hours was based on the argument that some plant TSs have used the 24-hour time interval without any adverse effects and there is an extremely small likelihood of limiting power shapes or limiting design basis events occurring during this period.

The response to RAI 8 provided additional technical justification as follows:

- Westinghouse fuel conditioning guidelines require at least { } cumulative hours of operation at a steady state power level in the last { } period in order for the fuel to be considered fully conditioned. The type of load-follow maneuvers that could result in heat flux hot channel factors that may challenge the F_Q limits will not take place before the surveillance is completed at 100 percent RTP.

- Prior to this surveillance, $F_Q^C(Z)$ has already been measured at least once at a reduced power level providing assurance that increasing power up to the next plateau will not exceed the F_Q limits and that the core is behaving as designed.

Based on these considerations identified in the response to RAI 8, the NRC staff determined changing the second surveillance time from 12 hours to 24 hours is acceptable. A discussion of the reasons for allowing 24 hours to complete F_Q surveillance is included in the Bases. Since the disposition for the increased completion time is based on Westinghouse fuel conditioning guidelines, adherence to such guidelines is a limitation of the NRC staff approval of the TR, as discussed in Section 5.1 of this SE.

4.6 DELETION OF NOTE IN SR 3.2.1.2

The NOTE in SR 3.2.1.2 required increasing the frequency to once per 7 EFPD for certain conditions until these conditions are satisfied. The intent of the NOTE in the current TS is to account for potential increases in $F_Q^W(Z)$ between surveillances. It required application of the greater of a 1.02 factor or a factor specified in the COLR whenever the measurement indicated that the maximum value of $F_Q^C(Z)$/K(Z) has increased. Alternatively, SR 3.2.1.2, "Verify that $F_Q^W(z)$ is within limit," is repeated once per 7 EFPD until $F_Q^W(Z)$ is within limit with the penalty factor applied or two successive flux maps indicate that $F_Q^C(Z)$/K(Z) has not increased.

The justification for eliminating the NOTE is that the required penalty factor is part of the $F_Q^W(Z)$ formulation in the new methodology. A penalty factor R_j is introduced and will be included in the COLR. The magnitude of the penalty factor is calculated based on the predicted margin trends and no additional assumptions or considerations are necessary.

The use of the new methodology and the built-in penalty factor has a number of advantages: (a) it will better capture the expected trend in the margin avoiding any lag in the application as was the case previously, (b) it avoids application of an arbitrary 2-percent minimum penalty, and (c) it eliminates the need for more frequent surveillance.

The issue addressed in this change is that past measurement trends are no longer being used (RAI 6b). This may be justified because, as stated in WCAP-17661, past measurement trends of $F_Q^C(Z)$/K(Z) may or may not be indicative of future margin trends.

The response to RAI 6 provided the following additional information:

- In some situations, measured trends in $F_Q^C(Z)$ may not always be indicative of the same margin trends in the measured $F_Q^W(Z)$. An example of such a situation is when the axial power distribution of the core is in transition from a cosine shape to a flattened saddle shape.

- During the initial onset of CIPS, a similar decreasing trend for both $F_Q^C(Z)$ and $F_Q^W(Z)$ may not necessarily occur. An increasing trend in the margin of $F_Q^C(Z)$ may occur due to a decrease in the radial peaking ($F_{XY}(Z)$) in the affected elevation of the highest power assemblies due to preferential accumulation of boron-containing crud there and the AFD being closer to zero or slightly negative for onset of CIPS. The trend in $F_Q^W(Z)$ is driven largely by the T(Z) or W(Z) surveillance factors.

Based on its review of the additional information provided by PWROG, the NRC staff determined that (1) it is an improvement that past measurement of $F_Q^C(Z)$ will no longer be used and (2) the NOTE in SR 3.2.1.2 for more frequent surveillance based on past measurements of $F_Q^C(Z)$ should no longer be required. The use of the penalty factor in the methodology to determine $F_Q^W(Z)$ is appropriate in assuring that this parameter is within limits. Thus, the NRC staff determined that the deletion of the NOTE, combined with the inclusion of a penalty factor in the $F_Q^W(Z)$ surveillance formulation is acceptable. The surveillance provides an acceptable confirmation that the power distribution remains within analyzed limits, including in instances where the surveillance indicates trends of reducing margin to $F_Q^W(Z)$ limits.

4.7 <u>CHANGE IN FREQUENCY OF SR 3.2.1.2 DURING POWER ESCALATION</u>

The current SRs for $F_Q^W(Z)$ (SR 3.2.1.2) are the same for both the CAOC and RAOC versions of the current F_Q Surveillance. The first part of the three-part surveillance frequency required assuring $F_Q^W(Z)$ within limits "once after each refueling prior to THERMAL POWER exceeding 75% RTP." This requirement is being changed to state that $F_Q^W(Z)$ must be verified to be within the limits following each refueling within 24 hours after achieving equilibrium conditions after THERMAL POWER exceeds 75 percent RTP.

The intent of this SR is to ensure that the F_Q will be maintained during future non-equilibrium operation within the allowed operating space.

The surveillance factors needed to perform an accurate $F_Q^W(Z)$ margin assessment at a very low power are difficult to generate without the advance knowledge of the expected operating power profile during the power ascension. The improved methodology presented in the submittal mitigates this concern partly. Conducting the surveillance after exceeding 75 percent power, ensures that surveillance will be conducted with appropriate steady state peaking factors measured at or near the peak power level and core conditions where future non-equilibrium conditions have the potential for challenging the fuel limits.

In this approach, power ascension within acceptable power peaking limits is assured, based on $F_Q^C(Z)$ surveillance. The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillance at reduced power conditions. For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at 50 percent RTP power level.

In addition, the following considerations apply, as stated in the submittal:

- Limitations on ramp rates and fuel conditioning requirements assure that initial startups following a refueling are slow and tightly controlled. As discussed in response to RAIs, Westinghouse fuel conditioning guidelines require at least { } cumulative hours of operation at a steady state power level in the last { } period in order for the fuel to be fully conditioned. With this procedure, following a refueling, non-equilibrium power shapes that may challenge the F_Q limits, are not expected to occur.

- Core power distribution measurements and physics testing performed at low powers (<50 percent RTP) confirm that the core is loaded properly and is operating consistent with expectations.

The other issue relating to this change is the 24 hours for conducting the surveillance after achieving the equilibrium conditions after THERMAL POWER exceeds 75 percent RTP. Because of fuel conditioning requirements, more than 24 hours will be spent at a steady state power level before the type of load follow maneuvers are permitted that may result in heat flux hot channel factors that may challenge the F_Q limits.

Based on the considerations discussed above, the NRC staff determined that the technical justification for changing the first frequency of SR 3.2.1.2 is acceptable. Primarily, the power ascension for the first startup of the cycle following a refueling is tightly controlled, such that $F_Q^C(Z)$ surveillance provides reasonable assurance that the core power distribution remains within analyzed limits. Further, the ability to perform an accurate $F_Q^W(Z)$ margin assessment is substantially improved once steady-state operation above 75-percent RTP is achieved. Since the justification for the modified SR is based in part on Westinghouse fuel conditioning guidelines, implementing licensees must adhere to such guidelines in order to implement this TR. This is a limitation of the NRC staff approval of this TR, as discussed in Section 5.1 of this SE.

4.8 CHANGES TO BASES

For the changes to RAOC and CAOC F_Q TSs (TS 3.2.1B and TS 3.2.1C), corresponding changes were made to the TS BASES. WCAP-17661-P provides the changes to the BASES to make them compatible with the changes made to the TSs. The changes to the BASES were reviewed and were discussed as part of the RAIs. The conclusion of the review was that additional discussions or clarifications for some aspects would be beneficial and provide improved clarity and understanding of the requirements in the TSs.

Additional discussions in the following areas were added in the BASES as part of the review of WCAP-17661:

1. Under the change for both RAOC and CAOC plants, Required Actions are now different for Conditions A, $F_Q^C(Z)$ not within limit, and B, $F_Q^W(Z)$ not within limit. When $F_Q^C(Z)$ is not within limit, reduction of THERMAL POWER is required along with reduction of setpoints and performance of SR 3.2.1.1 and SR 3.2.1.2. Whereas, when $F_Q^W(Z)$ is not within limits, two alternative actions may be applicable as discussed in the response to RAI 1. The first alternative action is included in Required Action B.1.1. This Required Action first requires implementation of a different operating space. If an appropriate operating

space cannot be implemented, then reduction of THERMAL POWER and setpoints and performance of SR 3.2.1.1 and SR 3.2.1.1 are required as an alternative. These aspects are discussed in the "Actions" section of the Bases.

The changes to the Condition B Required Actions, when $F_Q^W(Z)$ exceeds limits is intended to avoid THERMAL POWER reduction through implementation of a different operating space (Required Action B.1). However, when both $F_Q^C(Z)$ and $F_Q^W(Z)$ are not within limits, Required Action for $F_Q^C(Z)$ will require reduction of THERMAL POWER. The corresponding evaluation and action for $F_Q^W(Z)$ may be different. For example, Condition A ($F_Q^C(Z)$ not within limit) requires reduction of THERMAL POWER ≥ 1 percent for each 1 percent $F_Q^C(z)$ exceeds limit, but Condition B ($F_Q^W(Z)$ not within limit) may require reduction of THERMAL POWER as evaluated and set forth in the COLR.[12] As explained as part of the response to RAI 1, if both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, Required Action A.1 will be completed first due to the 15-minute Completion Time. Once the power level is reduced below that specified by Required Action A.1, the current operating peak power density will be restored to less than the value assumed in the safety analysis. As noted in the response to RAI 1, this Required Action may not ensure that the $F_Q^W(Z)$ limit is met.

The new Required Actions for Condition B are proposed to either implement a new operating space or a reduction in THERMAL POWER, and are required in order to ensure compliance with the $F_Q^W(Z)$ limit during future operation under transient conditions.

As a follow-up to the RAIs, these aspects are discussed and the BASES, which contain the clarifications regarding implementation of the proposed changes under different scenarios of $F_Q^C(Z)$ and $F_Q^W(Z)$ violations.

2. Under the proposed change, the new Required Action B.1.1 requires implementation of a RAOC/CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ within its limits. If control rod motion is needed as a result of entering Condition B and performing Required Action B.1, the fundamental measured power distribution will change as a result. As stated in response to RAI 5, in some cases, a revision to the allowed AFD band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion, in order to obtain and maintain the AFD within the allowed operating band. If the implementation of Required Action B.1.1 results in a need to move control rods, SR 3.2.1.1 and SR 3.2.1.2 should be performed to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. This is addressed through the addition of Required Action B.1.2 and associated discussions are included in the Bases.

3. Under the proposed changes, if the operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then THERMAL POWER must be reduced to less than the thermal power specified in the COLR. Also, AFD limits must be

[12] While Tables 6-10, 9-7, C-7, and F-7 in the TR show examples where the margin was defined in 5 percent decrements, the NRC staff understands that other decrements may be used, provided such decrements are analytically supported.

reduced by the amount specified in the COLR. As a practical matter, the number of discrete reduced power level evaluations included in the COLR is limited to three or less (an individual utility may opt for additional evaluation levels). If the required margin improvement exceeds the level of any pre-analyzed thermal power limits, the COLR will specify that the thermal power is limited to <50 percent RTP.

The requirement to reduce thermal power to <50 percent RTP is discussed in the BASES as part of the review of the submittal to ensure completeness of the actions required and to provide clear guidance to the plant operators.

4.9 INTERFACES WITH OTHER REQUIREMENTS

In assessing the changes to TS 3.2.1B and TS 3.2.1C, the interface of these requirements with other TS requirements was reviewed. The intent was to determine whether changes in these requirements may necessitate changes in other requirements.

Based on the review, two interfacing aspects were identified:

1. It was noted that TS 3.2.1A, Heat flux Hot Channel Factor ($F_Q(Z)$ (CAOC –F_{xy} Methodology)) is included for some plants. But, the concepts used in TS 3.2.1C are not used for TS 3.2.1A, i.e., TS 3.2.1A is not modified to use a different operating space and avoid reduction in THERMAL POWER. This issue was the topic of RAI 11.

2. TS 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," which provides limits and associated SRs for QPTR, may be affected by the proposed changes. The QPTR limits ensure that nuclear enthalpy rise hot channel factor ($F_{\Delta H}^N$) and $F_Q(Z)$ remain below their limiting values by preventing an undetected change in the gross radial power distribution. The QPTR limit of 1.02, at which corrective action is required, provides a margin of protection for both the departure from nucleate boiling ratio and linear heat generation rate contributing to excessive power peaks resulting from X-Y plane power tilts. Assurance is needed that the margin of protection is not being lost or that adequate margin of protection will still be maintained. This issue was the topic of RAI 12.

The response to RAIs 11 and 12 provided the following clarifying information:

1. The Required Actions in TS 3.2.1A are more conservative than those in proposed TS 3.2.1C. This is because TS 3.2.1A effectively treats all cases where the $F_Q(Z)$ limit is exceeded as if the plant is currently operating with a peak power density in excess of what is assumed in the safety analysis. The plants that have implemented TS 3.2.1A do not have to implement proposed TS 3.2.1C, since the resulting surveillance required by TS 3.2.1A is valid and conservative.

2. The implementation of a different operating space in the event that the performance of an $F_Q^W(Z)$ surveillance determines that the F_Q limit is not met would not significantly affect the indicated QPTR on the excore detector, nor would it affect the actual in-core power distribution symmetry.

3. Addition of a Required Action of performing SR 3.2.1.1 and SR 3.2.1.2, with a Completion Time of 72 hours, when a new operating space is implemented, which

results in control rod motion, will provide the requisite margin of protection. With this addition, the margin to safety analysis limits will be determined and confirmed after the implementation of a new operating space, including the effects of any existing QPTR. Once this is done, the same initial conditions are established with respect to the continued applicability of TS 3.2.4, as would otherwise have been present before the new operating space was implemented.

4.10 SUMMARY OF KEY REVIEW TOPICS

Based on the review described above, the NRC staff determined that the reformulated F_Q surveillance is acceptable. The following paragraphs reiterate the more significant of the NRC staff conclusions.

Regarding changes to the TS associated with $F_Q^C(Z)$, or the instantaneous heat flux hot channel factor, the NRC staff determined that the new required actions and completion times are more restrictive than the existing, and as such, concluded that they are acceptable.

Regarding the reformulation of the $F_Q^W(Z)$ surveillance, the NRC staff developed the following review considerations:

1. The use of a planar radial surveillance in conjunction with T(Z) factors eliminates axial sensitivities in the surveillance procedure, and eliminates the current reliance on Westinghouse guidance to adjust W(Z) factors when performing $F_Q^W(Z)$ surveillance in conditions significantly different from those assumed in the maneuvering analysis. As noted in Section 4.1 of this SE, the surveillance formulation, i.e., treatment of uncertainties and power distribution perturbations over the surveillance interval, is otherwise equivalent to the existing.

2. The PWROG proposed to introduce an additional factor to correct the surveillance parameter for conditions other than reference, i.e., A_{XY} and A_Q, and as discussed in Sections 4.1 and 5.2 of this SE, the NRC staff determined that the use of such parameters was acceptable, provided the methodological description provided in response to RAI 15 is followed.

3. The incorporation of the R_j correction factor, which conservatively adjusts for downward trends in $F_Q^W(Z)$, directly into the surveillance supports the elimination of the NOTE associated with SR 3.2.1.2, as discussed in Sections 4.1 and 4.4 of this SE.

Based on the above considerations, the NRC staff concluded that the reformulated $F_Q^W(Z)$ surveillance was acceptable.

Finally, the NRC staff considered the revisions to the Required Actions associated with not meeting the $F_Q^W(Z)$ LCO, and determined that they are acceptable. The revision provides for successively more restrictive operating spaces, which help to ensure that the core operates with sufficient margin to ensure that the peak power remains within analyzed limits. Perhaps more importantly, the operating spaces and associated margin factors are now analytically based. This improvement provides assurance that completion of the Required Actions ($F_Q^W(Z)$ is not within its limits) would ensure that the core power distribution remains within the limits analyzed in the ECCS evaluation. If the more restrictive operating spaces fail to provide the requisite

margin, similar reductions in rated thermal power level and reactor trip setpoints to those required for $F_Q^C(Z)$ become necessary.

In conclusion, the NRC staff review determined that the revisions to the heat flux hot channel factor TS were acceptable. The revisions provide a more robust means for performing the $F_Q^W(Z)$ surveillance, a series of more restrictive operating spaces if the $F_Q^W(Z)$ LCO is not met, and a more clearly defined set of SRs and Required Actions. The TS changes also provide reasonable assurance that a core operated in accordance with these TS will remain within the power distribution limits assumed in the facility safety analyses.

5.0 APPROVAL LIMITATIONS

The NRC staff review identified three limitations, adherence to which are necessary to ensure acceptable implementation of WCAP-17661.

5.1 LIMITATION 1: ADHERENCE TO FUEL CONDITIONING GUIDELINES

As discussed in Sections 4.5 and 4.7 of this SE, PWROG justified the specification of certain surveillance intervals on the concept that rapid changes in power level are precluded by fuel conditioning guidelines, which require slower ascensions in power, and maintenance of periodic thermal power plateaus. However, the TS do not make adherence to these fuel conditioning guidelines an obligation. Even so, the staff acceptance of the PWROG justification was based on any given facility's adherence to these guidelines.

Thus, licensees implementing this TR (i.e., making the TS changes contained herein) must confirm, in the implementation request, that they adhere to Westinghouse fuel conditioning guidelines. Otherwise, implementing licensees must demonstrate to the NRC staff that similar requirements exist to provide assurance that the frequency of abrupt changes in power level is kept appropriately low during the initial power ascension of a fuel cycle. This TR is not applicable if continued adherence to such guidelines is not practiced.

5.2 LIMITATION 2: USE OF A_{XY} AND A_Q

As discussed in Section 4.1.1 of this SE, the use of Methods 1 and 2 are acceptable for calculating A_{XY} and A_Q when performing RAOC and CAOC W(Z) surveillances, subject to the following limitations:

1. The NRC-approved methods provided in the response to RAI 15.b must be used to perform the surveillance-specific A_{XY} or A_Q calculations. Newer methods with similar capabilities may be considered acceptable provided the NRC staff specifically approves them for calculating A_{XY} and A_Q factors.

2. The depletion calculation used to determine the numerator and denominator of the A_{XY} or A_Q factor must be performed similarly to the original design calculation, as described in the response to RAI 15.c.

3. The use of Method 1 for calculating A_Q is only acceptable subject to the constraints discussed in the response to RAI 15.a. The surveillance Axial Offset must be within 1.5-percent of the target AO, and there must be assurance that the limiting $F_Q^W(Z)$ location does not lie within a rodded elevation at the time of surveillance.

5.3 LIMITATION 3: POWER LEVEL REDUCTION TO 50 PERCENT RTP

As noted in Section 4.3.2 of this SE, the use of 50 percent as the final power level reduction in the event of failed F_Q surveillance is not included in the TS, but rather in the BASES and in the COLR. As such, this final power level, 50 percent, must be implemented on a plant-specific basis and included in COLR input generated using this methodology, in order to use this TR.

6.0 CONCLUSIONS

Based on the review described in the preceding SE, and subject to the limitations provided in Chapter 5, the NRC staff has determined that the RAOC and CAOC surveillance formulations and required actions proposed in WCAP-17661 are acceptable. The TR may be considered approved for use by the NRC staff, for the purpose of justifying the TS changes contained therein.

7.0 REFERENCES

1. PWROG, "Improved RAOC and CAOC F_Q Surveillance Requirements," Reports WCAP-17661-P (Proprietary) and WCAP-17661-NP (Publicly Available), and Transmittal Letter OG-13-427, Project No. 694, January 2, 2014, ADAMS Package Accession No. ML14009A098.

2. U.S. NRC, "Standard Technical Specifications – Westinghouse Plants," NUREG-1431, Volume 1, Revision 4, "Specifications," and Volume 2, Revision 4, "Bases," April 2012, ADAMS Accession Nos. ML12100A222 (Volume 1) and ML12100A228 (Volume 2).

3. PWROG, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC RQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-16-273 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, September 13, 2016, ADAMS Package Accession No. ML16291A531.

4. PWROG, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-18-35 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, February 15, 2018, ADAMS Package Accession No. ML18053A269.

5. Westinghouse Electric Company, "Relaxed Axial Offset Control F_Q Technical Specification Actions," NSAL-09-5, Revision 1, September 23, 2009. This document was not formally transmitted to the NRC and it is not available in ADAMS.

6. U.S. NRC, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," Generic Letter 1988-16, October 4, 1988, ADAMS Accession No. ML031200485.

Attachment: Appendix

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APPENDIX: TABLES

TABLE 1: POWER DISTRIBUTION TERMS

1.A: Peaking Factors

Term	Name	Definition
F_Q	Total Heat Flux Hot Channel Factor	The ratio of peak to average power density in the core
F_{XY}	Planar Radial Peaking Factor	The ratio of peak-to-average power density in a radial core plane

1.B: Limits, Functions, and Multipliers

Term	Name	Definition
K(Z)	Axial shape function	Normalizes $F_Q(Z)$ as a function of core height. Included in COLR.
W(Z)	W(Z) function	Analytical ratios used in the current F_Q surveillance formulation to characterize the maximum expected increase in the surveillance *$F_Q(Z)$ x Power* relative to the non-equilibrium *$F_Q(Z)$ x Power.*
T(Z)	T(Z) function	Analytical ratios used in the improved F_Q surveillance formulation for RAOC plants to characterize the maximum transient P(Z)
CFQ	Rated thermal power (RTP) F_Q limit	Absolute limit applied to F_Q. Included in COLR. Term used in STS and STS Bases (Ref. 2).
P	Fraction of RTP	Used to scale the measured power distribution based on the core operating power level. Term used in STS and STS Bases (Ref. 2).
P_{rel}	Core average relative power	Same as fraction of RTP, above, but used in surveillance formulations presented in WCAP-17661.
P_{rel}^{ss}	Surveillance relative power	Actual power divided by the rated thermal power at the time of surveillance
P(Z)	Core average axial power shape	Planar average power at elevation Z, divided by volume average power of the core
$P(Z)_{ref}^{p}$	Relative axial power shape	Relative axial power predicted at the reference condition
PFXY	Power factor multiplier	Power factor multiplier for F_{XY}. Provided in the COLR.
A_{XY}	Correction factor for RAOC surveillance conditions	Used to adjust the $F_Q^W(Z)$ value in instances when the surveillance is conducted in a different condition, i.e., thermal power level and control rod insertion, than the reference condition (typically hot full power, all rods out, equilibrium xenon). May be included in the COLR; could also be calculated using a 3-D core simulator for specific surveillance conditions.
A_Q	Correction factor for CAOC surveillance conditions	
R_j	Penalty factor	Used to account for reductions in F_Q margin that may occur for trends that follow burnup over the surveillance interval

TABLE 1: POWER DISTRIBUTION TERMS (CONTINUED)

1.C: F_Q Terms		
Term	**Name**	**Definition**
$F_Q(Z)$	Heat flux hot channel factor	Maximum local heat flux on the surface of a fuel rod at core elevation Z, divided by the average fuel rod heat flux. In the WCAP-17661 methodology, this term is approximated by multiplying $F_{XY}(Z)$ by P(Z).
$F_Q^M(Z)$	Measured heat flux hot channel factor	Measured value of $F_Q(Z)$ obtained directly from the flux map results.
$F_Q^C(Z)$	--	The measured value, $F_Q^M(Z)$, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
$F_Q^W(Z)$	Transient $F_Q(Z)$	The maximum $F_Q(Z)$ calculated to occur in normal operation over the next surveillance interval. Includes margin for (1) fuel manufacturing tolerances, (2) flux map measurement uncertainty, and (3) operational transients anticipated over the next surveillance interval. The product of $F_Q^C(Z)$ and W(Z).
F_Q^{PR}	--	The predicted value of the Heat Flux Hot Channel Factor. A maximum value that includes load follow impacts.
F_Q^{RTP}	Rated thermal power F_Q limit	Same as CFQ.

1.D: F_{XY} Terms		
Term	**Name**	**Definition**
$F_{XY}(Z)$	Height-dependent radial peaking factor	Radial peaking factor, measured using the incore detector system, at a given plane of the core.
F_{XY}^M	--	The measured value of F_{XY} obtained directly from the flux map results.
F_{XY}^C	--	The measured value, F_{XY}^M, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
F_{XY}^{RTP}	--	The limit of F_{XY} at RTP.
F_{XY}^L	--	The limit of F_{XY} at the current thermal power level.

TABLE 2: SUMMARY OF PROPOSED CHANGES

2.A: Title			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B, Title	$F_Q(Z)$(RAOC-W(Z) Methodology)	$F_Q(Z)$(RAOC-T(Z) Methodology)	Use of a different methodology requires the name change

2.B: Actions, Condition A			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B and 3.2.1C, Required Actions A.2 and A.3	"... 1% for each 1% $F_Q^C(Z)$ exceeds limit"	"... 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."	Revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance. The current wording is only appropriate if the surveillance is performed at full power. The new wording will require greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(z)$ exceeds its limit. (WCAP, Section 3.2.2, pg.3-12)
NOTE in Condition A	Required Action A.4 shall be completed whenever this Condition is entered.	Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.	Makes it consistent with other changes.

1 TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.C: Actions, Condition B			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
TS 3.2.1B and 3.2.1C, New Required Action B.1.1		B.1.1 states, "Implement a RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits."	Implementation of a New RAOC/CAOC operating space restores $F_Q^W(Z)$ within limits.
New Required Action B.1.2		B.1.2 states, "Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space."	When control rod motion is required, surveillance assures that $F_Q^W(Z)$ remains within limits.
TS 3.2.1B, Required Action B.2.1 (previously B.1)	Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER and reduce AFD limits as specified in the COLR.	Evaluations in the COLR will provide the applicable power level and AFD limits to assure $F_Q^W(Z)$ within limits.
TS 3.2.1C, Required Action B.2.1 (previously B.1)	Reduce THERMAL POWER ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER as specified in the COLR.	Core models provide basis for determining the axial location of the minimum margin in the actual core.
TS 3.2.1B, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"… 1% for each 1% that the maximum allowable power of the AFD limits is reduced"	"… 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	With the change, peak power densities will remain within limits of the safety analyses.
TS 3.2.1C, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"… 1% for each 1% $F_Q^W(Z)$ exceeds limits"	"…1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	Prior requirements may not ensure that non-equilibrium operation was bounded by the maximum power distribution assumptions in all circumstances.
TS 3.2.1B, Completion Time for Required Action B.2.4	"Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."	"Prior to increasing THERMAL POWER above the limit of Required Action B.2.1"	Proposed change in TS 3.2.1B will make it consistent with the Completion Time defined in TS 3.2.1C. Completion Time in TS 3.2.1C did not need any changes.
NOTE in Condition B	Applicable whenever Condition B is entered	Moved (with addition "prior to increasing THERMAL POWER above the limit of Required Action B.2.1") under Required Action B.2.1, i.e., applicable when Required Actions under B.2.1, B.2.2, B.2.3 and B.2.4 are entered.	Required Action option B.1 assumes that a RAOC operating space specified in the COLR satisfies $F_Q^C(Z)$ and $F_Q^W(Z)$ limits if no control rod (CR) motion is needed. Required Action B.1.2 requires surveillance CR motion is needed. Required Action B.2.4 institutes performance of the SRs if option B.2 is used.

TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.D: Surveillance Requirements (SRs)			
TS Section and Requirements	**Current Specifications**	**Revised Specifications**	**Justifications presented in the WCAP**
NOTE for SRs	NOTE states that "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."	The NOTE is deleted.	The NOTE has been a source of confusion and interpreted differently by various utilities. Existing frequencies, together, are unambiguous and appropriately verify $F_Q^C(Z)$ during the initial power escalation and throughout the operating cycle.
SR 3.2.1.1, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions ..."	"Once within [24] hours after achieving equilibrium conditions ..."	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.
NOTE for SR 3.2.1.2	The NOTE in SR 3.2.1.2 requiring increasing SR frequency considering an increase factor for $F_Q^W(Z)$ when increase from previous evaluation has been noted.	The NOTE is deleted.	The penalty factor in the improved methodology is based on predicted rather than measured trends in transient F_Q margin, and is applied when SR 3.2.1.2 is performed. It is argued that the past measurement trends are not indicative of future margin trends.
SR 3.2.1.2, 1st requirement in the Frequency column	"Once after each refueling prior to THERMAL POWER exceeding 75% RTP"	"Once after each refueling within [24] hours after achieving equilibrium conditions after THERMAL POWER exceeds 75% RTP."	Verification will still be performed within a reasonable time and prior to extended non-equilibrium operation at power levels where the maximum peak linear heat rate could potentially be challenged.
SR 3.2.1.2, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THEMAL POWER at which $F_Q^W(Z)$ was last verified."	"Once within [24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THEMAL POWER at which $F_Q^W(Z)$ was last verified."	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.

Program Management Office
1000 Westinghouse Drive, Suite 380
Cranberry Township, PA 16066

WCAP-17661- P/NP, Revision 1
Project Number 99902037

August 2, 2018

OG-18-188

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Subject: PWR Owners Group
Transmittal of the Response to the Revised Draft Safety Evaluation (DSE) for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795)

References:

1. Letter OG-13-427, "Submittal of WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated January 2, 2014

2. NRC Letter of Acceptance for Review of PWROG Topical Report WCAP-17661-P/NP, Revision 1, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 1, 2014

3. NRC Letter for Request for Additional Information RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated December 24, 2014 (TAC NO. MF3348)

4. Letter OG-16-273, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," dated September 13, 2016

5. Email from the NRC (Benney) to the PWROG (Holderbaum), Request for Additional Information, RAI 15, RE: PWROG Topical Report WCAP-17661-P/NP, Revision 1 "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated July 27, 2017

6. OG-18-35, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795", February 15, 2018.

7. Email from the NRC (Benney to the PWROG (Holderbaum), Draft Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Pressurized Water Reactor Owners' Group Licensing Topical Report WCAP-17661, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," dated Monday, April 30, 2018

The purpose of WCAP-17661-P/ WCAP-17661-NP is to develop an improved FQ Technical Specification (TS) that addresses the issues associated with the current TS. Specifically, the new TS will minimize, to the extent possible, the sensitivity of the Surveillance to differences between the measured and predicted axial offset.

WCAP-17661-P/ WCAP-17661-NP also clarifies the requirements for part-power Surveillances (i.e., when they must be performed) and minimize the potential for overly conservative part-power Surveillance results. Finally, it corrects a non-conservative Required Action in TS 3.2.1 B in NUREG-1431, and provides appropriate Required Actions to be taken, when a Surveillance identifies that the Technical Specification FQ limit has been exceeded.

On January 2, 2014, in accordance with the Nuclear Regulatory Commission (NRC) Topical Report (TR) program for review and acceptance, the Pressurized Water Reactor Owners Group (PWROG) requested formal NRC review and approval of WCAP-17661-P/NP, Revision 1, for referencing in regulatory actions (Reference 1).

The NRC Staff has determined that additional information is needed to complete the review per letter dated December 24, 2014 (Reference 3). On September 13, 2016 the PWR Owners Group provided a response the Request for Additional Information (RAI) (Reference 4).

On July 27, 2017, the NRC Staff determined that additional information was needed to complete the review of the Topical Report and issued RAI-15 (Reference 5). The PWROG provided a response to NRC RAI-15 (Reference 5) associated with WCAP-17661- P/ WCAP-17661-NP, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," Revision 1, and revisions to other documents associated with the response to RAI 15, (Reference 6).

On April 30, 2018, the NRC Staff provided the PWROG with the Draft Safety Evaluation (DSE) for review and comment (Reference 7).

The purpose of this letter is to transmit the PWROG comments on the NRC's DSE for WCAP-17661- P/ WCAP-17661-NP, "Improved RAOC and CAOC FQ Surveillance Technical Specifications," Revision 1 (Reference 7).

Please note that the information contained in brackets, as identified by the NRC staff in the DSE, is information that is Proprietary to Westinghouse, and therefore both a Proprietary and Non-Proprietary version of the Final Safety Evaluation should be issued.

Enclosed are:

1. Comments on the DSE for WCAP-17661-P/ WCAP-17661-NP, Revision 1 (PA-LSC-0795) (Non-Proprietary)
2. Revision to the Technical Specification (TS) Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 (Non-Proprietary)
3. Revision to the TS Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 and OG-18-35 (Non-Proprietary)
4. WCAP-17661-P/ WCAP-17661-NP, Revision 1 Markup Pages (PA-LSC-0795) (Non-Proprietary)
5. WCAP-17661-P/ WCAP-17661-NP, Revision 1 Markup Pages (PA-LSC-0795) (Proprietary)

Also enclosed are the Westinghouse Application for Withholding Proprietary Information from Public Disclosure, CAW -18-4779, accompanying Affidavit, Proprietary Information Notice, and Copyright Notice (Enclosure 6).

As Item 5 contains information proprietary to Westinghouse Electric Company LLC ("Westinghouse"), it is supported by an Affidavit signed by Westinghouse, the owner of the information. The Affidavit sets forth the basis on which the information may be withheld from public disclosure by the Nuclear Regulatory Commission ("Commission") and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the copyright or proprietary aspects of the item listed above or the supporting Westinghouse Affidavit should reference CAW-18-4779 and should be addressed to James A. Gresham, Consulting Engineer, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2 Suite 259, Cranberry Township, Pennsylvania 16066.

Correspondence related to this transmittal should be addressed to:

Mr. W. Anthony Nowinowski, Executive Director
PWR Owners Group, Program Management Office
Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

If you have any questions, please do not hesitate to contact me at (805) 545-4328 or Mr. W. Anthony Nowinowski, Program Manager of the PWR Owners Group, Program Management Office at (412) 374-6855.

Sincerely yours,

Ken J Schrader

Ken Schrader, COO & Chairman
PWR Owners Group

JKS:am

cc: PWROG Licensing Subcommittee (Participants of PA-LSC-0795)
PWROG PMO
PWROG Steering and Management Committee
J. Gresham, Westinghouse
J. Andrachek, Westinghouse
J. Moorehead, Westinghouse
M. Hone, Westinghouse
J. Brown, Westinghouse
B. Benney, US NRC
J. Drake, US NRC

Enclosure 1: LTR-PL&E-18-029, Rev. 0, Attachment 1, "Comments on the Revised DSE for WCAP-17661-P/ WCAP-17661-NP, Revision 1" (PA-LSC-0795) (Non-Proprietary)

Enclosure 2: LTR-PL&E-18-029, Rev. 0, Attachment 2, "Revision to the Technical Specification (TS) Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 (Non-Proprietary)

Enclosure 3 LTR-PL&E-18-029, Rev. 0, Attachment 3, "Revision to the TS Bases Markups for TS 3.2.1B and TS 3.2.1C that were transmitted via OG-16-273 and OG-18-35" (Non-Proprietary)

Enclosure 4 LTR-PL&E-18-029, Rev. 0, Attachment 4, "WCAP-17661-P/ WCAP-17661-NP, Revision 1 Markup Pages" (PA-LSC-0795) (Non-Proprietary)

Enclosure 5: LTR-PL&E-18-029, Rev. 0, Attachment 5, "WCAP-17661-P/ WCAP-17661-NP, Revision 1 Markup Pages" (PA-LSC-0795) (Proprietary)

Enclosure 6: Affidavit for Withholding, CAW-18-4779 (Non-Proprietary) with accompanying Affidavit, Proprietary Information Notice and Copyright Notice

Westinghouse Non-Proprietary Class 3

ATTACHMENT 1

Comments on the Revised DSE for

WCAP-17661-P/ WCAP-17661-NP, Revision 1

(PA-LSC-0795) (Non-Proprietary)

(48 total pages including Attachment 1 cover page)

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO PRESSURIZED WATER REACTOR OWNERS' GROUP

LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

~~**PROPRIETARY INFORMATION NOTICE:** This document contains proprietary information owned by Westinghouse Electric Company LLC that must be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17.~~

~~Proprietary information is enclosed in curly brackets and set in bold-face type. **{This sentence is an example of the proprietary designation.}**~~

~~Curly brackets were selected because square brackets denote other types of text in this document.~~

Enclosure

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Contents

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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LICENSING TOPICAL REPORT WCAP-17661

"IMPROVED RAOC AND CAOC FQ SURVEILLANCE TECHNICAL SPECIFICATIONS"

PROJECT NO. 694

1.0 INTRODUCTION

The Pressurized Water Reactor Owners Group (PWROG) submitted Topical Report (TR) WCAP-17661[1] for U.S. Nuclear Regulatory Commission (NRC) staff review by letter dated January 2, 2014 (Ref. 1). The TR provides the technical basis for updates to Technical Specification (TS) 3.2.1, "Heat Flux Hot Channel Factor," as presently contained in NUREG-1431, "Standard Technical Specifications – Westinghouse Plants" (Ref. 2). Specifically, the TR addresses (1) potential non-conservatisms in Required Action B.1 of TS 3.2.1B, which is applicable to Relaxed Axial Offset Control (RAOC) plants, and (2) "the sensitivity of the formulation of the associated Surveillance Requirement (SR) to the differences between the measured and predicted surveillance power shapes at both nominal and part power conditions" (Ref. 1). The TR was supplemented by letters dated September 13, 2016 (Ref. 3) and February 15, 2018 (Ref. 4). The supplements provided responses to the NRC staff requests for additional information (RAIs).

In addition to the changes described above, WCAP-17661 includes several other improvements to Versions B and C of TS 3.2.1. TS 3.2.1B is the version that is applicable to plants that have implemented the RAOC methodology, whereas TS 3.2.1C is the version that is applicable to plants that use the Constant Axial Offset Control (CAOC) – W(Z) methodology. Meanwhile, TS 3.2.1A, the version of the TS that is applicable to plants using the CAOC-F_{XY} methodology remains unchanged, and this TR does not apply to such plants.

All of the TS changes described and justified in WCAP-17661 are described in detail in Section 3.0 of this safety evaluation (SE).

1.1 BACKGROUND: POWER DISTRIBUTION TERMS

The TR relates to peaking factors that are used to describe the power distribution at Westinghouse Electric Company (Westinghouse)-designed plants. These factors, and the various functions, factors, and limits that are used to manipulate the peaking factors in order to ensure they provide appropriate margins for uncertainties and operational transients over a given surveillance interval, are summarized in Table 1, located in the appendix to this SE. The table first defines the peaking factors, then provides the limits, functions, and multipliers, and finally provides definitions for the various different versions of each peaking factor.

[1] As noted in the citation for Reference 1, WCAP-17661 exists in both proprietary (WCAP-17661P) and publicly available (WCAP-17661NP) formats. This SE is applicable to both formats, and refers to the TR generally without the proprietary designator (i.e., WCAP-17661).

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It is useful to refer to Table 1 alongside subsequent sections of this SE, in which the terms contained in the table are frequently used in discussing the algebraic formulations of the surveillance terms and operating limits.

1.2 PURPOSE OF TOPICAL REPORT

In 2009, Westinghouse identified a non-conservatism associated with the limiting conditions for operation (LCOs) and associated SRs for the Heat Flux Hot Channel Factor ($F_Q(Z)$) for Westinghouse nuclear power plants. Specifically, it was recognized that the Required Actions in NUREG-1431 (Ref. 2), in situations where the plant does not meet an F_Q limit, are not as conservative as previously understood.

Westinghouse issued Nuclear Safety Advisory Letter (NSAL) 09-5, "Relaxed Axial Offset Control F_Q Technical Specification Actions," to address the situation on an interim basis (Ref. 5). The NSAL required four specific actions, in addition to the current specific Required Actions contained in the plant-specific F_Q TSs, if it was determined that F_Q was not within the LCO limit following a surveillance performed at ≥ 75 percent rated thermal power (RTP). These actions are very conservative so that they envelop all plants.

Another potential~~The~~ non-conservatism becomes apparent in plants using RAOC rather than CAOC. A key surveillance parameter, $F_Q^W(Z)$, is the product of analytical factors and surveillance measurements. The analytical factors are derived before each reload, and must assume a reference condition for the surveillance, even though the surveillance takes place after the plant returns to power, and hence, well after the analytical factors are derived. The initial surveillance condition is not necessarily the same as the reference condition, and this can lead to an inaccuracy that is non-conservative.

Comment [a1]: The text "The non-conservatism becomes apparent…." Infers that this paragraph is continuing to discuss the item discussed in the 2nd paragraph (i.e., the non-conservative Required Action identified in NSAL-09-5). However, the 3rd paragraph discusses a different issue (i.e., the sensitivity of RAOC Surveillance measurements to the conditions where the Surveillance is performed). Therefore, the first sentence should be revised to: "Another potential non-conservatism becomes apparent…."

The PWROG submitted WCAP-17661 in order to develop a permanent resolution to the problem and define appropriate revisions to the standard TS (STS) related to the F_Q surveillance. The intent is to replace the temporary actions required by the NSAL in case F_Q is found outside the LCO limits with Required Actions that will assure that plant operation will remain bounded by the facility safety analyses. The PWROG submitted WCAP-17661 to the NRC, requesting approval in order to make subsequent changes to the STS, NUREG-1431. The specific TS that are proposed to be changed are TS 3.2.1B, Heat Flux Hot Channel Factor (F_Q (Z) (RAOC-W(Z) Methodology)) and TS 3.2.1C, Heat Flux Hot Channel Factor (F_Q (Z) (CAOC-W(Z) Methodology)).

1.3 SUMMARY OF CHANGES

The following discussion provides a brief summary of the changes set forth in WCAP-17661. A detailed discussion of each change is provided in Section 3.0 of this SE, and a summary of changes in tabular format is provided in Table 2, in the appendix.

1.3.1 Limiting Conditions for Operation (Unchanged)

The LCOs for TS 3.2.1B and 3.2.1C remain unchanged. The requirement, in both versions of the LCO, remains for $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, to remain within the limits specified in the core operating limits report (COLR). The approximations for these parameters, however, will change as discussed in the succeeding sections.

1.3.2 Core Operating Limits Report Content

Based on the discussion contained in the TR, the NRC staff determined that the typical COLR content[2] will change. As outlined below, the amount of the COLR content related to $F_Q^W(Z)$ will increase. Primarily, this increase stems from the following items, which will be newly included in the COLR:

1. The definition of new RAOC operating spaces (ROSs) or CAOC operating spaces (COSs),

2. The inclusion of a normalization factor $A_{XY}(Z)$ for RAOC, or $A_Q(Z)$ for CAOC[3],

3. The definition of a penalty factor, R_j, and

4. The inclusion of separate control rod insertion limits, transient functions, penalty factors, and axial flux difference (AFD) bands for the new ROSs and COSs.

Comment [a2]: Footnote 3 is not consistent with Section 5.2, Limitation 2, and should be revised to be consistent with Section 5.2, Limitation 2. As written, Footnote 3 prohibits the use of $A_{XY}(z)$ and $A_Q(z)$ values less than 1.0.

The COLR will also include newly formulated, cycle-specific limits associated with implementing the proposed Required Actions to take in the event that completion of a SR indicates that an LCO is not met.

1.3.3 Surveillance Requirements

For RAOC plants, rather than formulating the $F_Q^W(Z)$ surveillance parameter by using a core-wide, three-dimensional surveillance to measure F_Q, the surveillance will now determine a synthesized F_Q using a planar F_{XY} surveillance and multiplying it by a reference axial power shape. The surveillance is repeated for each plane in the core, from 15- to 85-percent core height to determine a maximum to compare to the limit.[4] The philosophy of using multipliers to the measured value to provide margin for manufacturing tolerances, surveillance uncertainty, and operational transients over the following surveillance interval remains unchanged. However, the formulation of the transient function is modified.

In addition, some language contained in the SRs has been modified to add clarity, and minor changes to some surveillance frequencies have been proposed.

1.3.4 Required Actions

The Required Actions associated with both $F_Q^W(Z)$ and $F_Q^C(Z)$ have been modified. These modifications serve two primary purposes: (1) to provide more explicit limitations on thermal

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[2] This list was formulated by reviewing a sample of COLRs submitted on several dockets. The content of a specific COLR varies from plant to plant, and not all plants may have the exact content listed here.
[3] As discussed in Section 4.1, the NRC staff determined that the use of such factors, when less than unity, was not acceptable.
[4] Per NUREG-1431, "The top and bottom 15-percent of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions" (Ref. 2, Volume 2, SR 3.2.1.2). Note that the top and bottom 15-percent exclusion zones are typical, however, the exclusion zone is established on a cycle specific basis to ensure that the limiting margin location is surveilled. Therefore, for a specific operating cycle, exclusion zones smaller than 15-percent may be specified.

power and reactor trip setpoints in the condition that the SRs are not met, and (2) to accommodate the implementation of successively restrictive operating spaces in the event that the SRs are not met.

2.0 REGULATORY EVALUATION

The specification of and adherence to limits on F_Q ensures that the value of the initial total peaking factor assumed in the accident and transient analyses remains valid. As noted in NUREG-1431, the F_Q limits assumed in the emergency core cooling system (ECCS) performance evaluation are typically limiting relative to the F_Q limits assumed in safety analyses for other postulated accidents and anticipated operational occurrences. Even if the ECCS limits are less limiting than those determined by another safety analysis, specification of and adherence to the F_Q limits still ensures that facility operation remains bounded by the safety analyses.

The regulatory evaluation thus identifies performance requirements and design criteria contained within Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities." The applicable requirements related to the specific content of TSs, relative to the facility safety analysis, are also identified, including appropriate guidance for administratively controlling such specifications. Finally, Section 2.3 of this SE summarizes the way in which the regulatory requirements apply specifically to the reformulated TS for F_Q.

2.1 PERFORMANCE REQUIREMENTS AND DESIGN CRITERIA

The performance requirements and design criteria applicable to the power distribution assumed in the safety analysis are those that pertain to accident and transient analysis. Primarily these include the requirements contained in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," and General Design Criterion (GDC) 10, contained in Appendix A, "General Design Criteria for Nuclear Power Plants." Since the TS also prescribe appropriate remedial action to follow if TS limitations are not met, some additional GDCs relative to the reactor protection and reactivity control systems also apply, as listed below.

The requirements in 10 CFR 50.46 state, in part, that ECCS shall be designed such that an evaluation performed using an acceptable evaluation model demonstrates that acceptance criteria, set forth in 10 CFR 50.46(b), including peak cladding temperature, cladding oxidation, hydrogen generation, maintenance of coolable core geometry, and long-term cooling are met for a variety of hypothetical loss-of-coolant accidents (LOCAs), including the most severe hypothetical LOCA.

GDC 10, "Reactor Design," states as follows:

> The reactor and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.

GDC 20, "Protection System Functions," states as follows:

> The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated

> operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety.

GDC 26, "Reactivity Control System Redundancy and Capability," states as follows:

> Two independent reactivity control systems of different design principles shall be provided. One of the systems shall use control rods, preferably including a positive means for inserting the rods, and shall be capable of reliably controlling reactivity changes to assure that under conditions of normal operation, including anticipated operational occurrences, and with appropriate margin for malfunctions such as stuck rods, specified acceptable fuel design limits are not exceeded. The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) to assure acceptable fuel design limits are not exceeded. One of the systems shall be capable of holding the reactor core subcritical under cold conditions.

2.2 TECHNICAL SPECIFICATIONS

The requirements for TS are set forth in 10 CFR 50.36, "Technical Specifications." Specific categories of TS are provided in 10 CFR 50.36(c). These include LCOs and SRs. If an LCO is not met, the facility must be shut down, or other acceptable remedial action must be taken. SRs are intended to ensure that facility operation remains within the LCOs. NRC Generic Letter (GL) 88-16, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," established the NRC position that licensees could remove the cycle-specific values of certain operating limits from the TS and maintain them in a COLR, provided that certain requirements were met (Ref. 6).

Paragraph (c)(2) of 10 CFR 50.36 discusses LCOs, stating that such TSs are the lowest functional capability or performance levels of equipment required for safe operation of the facility. The requirements indicate that LCOs must be established for each item that meets one or more of four criteria. One of the criteria is a process variable, design feature, or operating restriction that is an initial condition of a design-basis accident (DBA) or transient analysis that either assumes the failure of or presents a challenge to the integrity of a fission product barrier.

Paragraph (c)(3) of 10 CFR 50.36 states:

> Surveillance requirements are requirements relating to test, calibration, or inspection to assure that the necessary quality of systems and components is maintained, that facility operation will be within safety limits, and that the LCOs will be met.

The guidance contained in GL 88-16 provides a means by which the values of certain parameters could be determined and modified on a cycle-specific basis without prior NRC review and approval. In order to implement this guidance, licensees are required to do the following: (1) use NRC-approved methodology to determine the operating limits; (2) include a list, in the TS Administrative Controls section, of the references used to determine the operating limits; and (3) maintain the limits in a COLR, which must be submitted to the NRC for information.

2.3 DISCUSSION

The safety analyses required to establish that a facility will comply with the requirements of 10 CFR 50.46, and with GDC 10, require as input the peak fuel power and the power distribution. Since the peak power and the power distribution are initial conditions of DBA and transient analyses, facility operation must be controlled by LCOs that are established based on these parameters. Hence, Westinghouse pressurized water reactors (PWRs) have LCOs relative to F_Q. In accordance with 10 CFR 50.36(c)(2), the LCO is accompanied by SRs to ensure that the LCO is satisfied. At plants that have implemented GL 88-16, specific parameter values may be administratively controlled, and in such cases these parameters must be determined in accordance with NRC-approved methodology, and contained in the facility COLR.

If during performance of a SR F_Q is determined not to be within the limit then the LCO is not met, and the TS remedial actions must be followed to ensure that facility operation remains safe. These remedial actions are based on (1) restoring compliance with the LCO, and (2) adjusting the reactor protection system settings so that the functionality required by GDCs 20 and 26 is maintained.

The NRC staff evaluation of the modified TS contained in WCAP-17661 considered whether the modified TS are consistent with the regulatory requirements identified above. In particular, the NRC staff evaluated whether (1) the revised TS LCOs ensure that facility operation remains within the bounds established by the safety analysis, (2) the reformulated SRs ensure that facility operation meets the LCOs, and (3) the revised required actions and completion times, applicable if either or both of the LCOs are not met, are appropriate to ensure that compliance with the unmet LCOs is restored, and that facility operation remains safe.

3.0 DETAILED SUMMARY OF CHANGES

This section expands on the discussion provided in Section 1.3 of the SE.

3.1 IMPROVED METHODOLOGY TO DEFINE RAOC AND CAOC F_Q SURVEILLANCE

The current $F_Q(Z)$ surveillance relies on a combination of analytical factors and periodic measurements to provide assurance that core operation does not lead to unacceptable local power peaking. This works well for CAOC plants but for RAOC plants the approach is not as robust. Specifically, the problem is that prior to each reload when the analytical factors are calculated, there has to be a prediction of the axial power shape at the time of surveillance and this is usually not known.

To understand how the new methodology is expected to overcome this problem, consider how the following F_Q surveillance parameter is defined:

$$F_Q^W(Z) = W(Z)[F_Q\,(Z)]^M_{Surv} * U_F \tag{1}$$

where *W(Z)* is an analytically derived factor and the $F_Q(Z)$ in the brackets is the measured value (*M*) at the time of the surveillance (*Surv*). An uncertainty factor U_F is also added to this equation to account for both instrument uncertainty and fuel manufacturing uncertainty. $F_Q^W(Z)$ must be less than or equal to a limiting value found in the COLR. It is related to the $F_Q^C(Z)$ surveillance parameter important to monitor steady state operation:

Comment [a3]: It is a "measurement" uncertainty, not an "instrument" uncertainty

$$F_Q^W(Z) = W(Z) * F_Q^C(Z) \tag{2}$$

The analytically derived factor $W(Z)$ { } is relative to a reference condition. It is calculated prior to operation of a cycle and found in the COLR for use during the surveillances.

$$\left\{ \qquad \right\} \tag{3}$$

where { }. The denominator is the predicted (*p*) steady state value at the reference (*ref*) core condition. The latter is typically at hot full power with all control rods out and equilibrium xenon, which are not necessarily the conditions at which the surveillance F_Q is measured.

If the reference condition in Equation (3) is identical to the surveillance value in Equation (1) then the surveillance is done correctly, but if it is not, an error can be introduced. The new methodology replaces the factors in Equation (1) with equivalent factors which do not have the

overt dependence that the reference and surveillance axial distributions are identical. The new surveillance parameter is derived in detail in WCAP-17661. It is[5]

$$F_Q^W(Z) = \frac{[T(Z)]^{COLR}}{P_{rel}^{ss}} A_{XY}(Z) * [F_{XY}\ (Z)]_{SURV}^{M} * U_F\ *\ R_j \tag{4}$$

Equation (4) uses both new analytical factors and new surveillance factors. The equation also includes a new penalty factor R_j. In this equation $[T(Z)]^{COLR}$ is the pre-calculated function

$$\left\{ \qquad\qquad\qquad\qquad \right\} \tag{5}$$

where $[P(Z)]_{ref}^{p}$ is the relative axial power predicted at the reference condition. P_{rel}^{ss} is the relative power level (actual power divided by the RTP) at the time of the surveillance. An additional analytical factor A_{XY} is included in Equation (4) to account for differences between the reference and surveillance conditions:

$$\left\{ \qquad\qquad\qquad \right\} \tag{6}$$

The proposed approach (Equation (4)) is made consistent by using the measured $F_{xy}(Z)$ rather than $F_Q(Z)$ as in Equation (1) or (2). There is also the same factor U_F as in Equation (1) to take into account uncertainties.

The penalty factor R_j for surveillance time point j is used to account for the expected decrease in margin due to non-equilibrium operation over the period of operation prior to the next performance of SR 3.2.1.2.

The above approach to redefine the surveillance parameter factors is not needed for CAOC plants. However, analogous changes are proposed to the surveillance equation for CAOC plants to adjust for differences in the reference and surveillance conditions, and to implement the same penalty R_j for any expected decrease in margin prior to performing the next surveillance. The result changes the CAOC surveillance parameter from that shown in Equation (2) to the following:

$$F_Q^W(Z) = \frac{[W(Z)]^{COLR}}{P_{rel}^{ss}} * A_Q(Z) * \left[F_Q(Z)\right]_{Surv}^{M} * U_F\ *\ R_j \tag{7}$$

where the adjustment ratio is:

$$\left\{ \qquad\qquad\qquad \right\} \tag{8}$$

[5] Only the situation for surveillance done above a relative power of 0.5 (i.e., 50-percent RTP) is considered herein. The situation below this power is an obvious extension and is given in WCAP-17661.

According to WCAP-17661, the usual case is that surveillances are performed at core conditions close to the conditions corresponding to the target axial offset measurement and hence, $A_Q(Z)$ will be very close to 1.0.

3.2 PROPOSED CHANGES TO TECHNICAL SPECIFICATIONS 3.2.1B AND 3.2.1C

The improved methodology for F_Q surveillance was used to define a number of changes to both RAOC and CAOC F_Q surveillance, i.e., both TS 3.2.1B and TS 3.2.1C are proposed to be revised. One obvious change is to substitute T(Z) for W(Z) in the title of TS 3.2.1B. A summary of the other proposed changes in each TS is given below and further summarized in Table 2.

3.2.1 Changes to NOTE and Required Actions for Condition A: $F_Q^C(Z)$ not Within Limit

Changes are considered for the NOTE to Condition A and for Required Actions A.2 and A.3. The Changes are the same for both RAOC and CAOC plants.

The NOTE for Condition A stated, "Required Action A.4 shall be completed whenever this Condition is entered." It is proposed to be changed as follows:

> Required Action A.4 shall be completed whenever this Condition is entered *prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.*

When $F_Q^C(Z)$ is not within limit, the Required Actions were defined as follows:

(1) Reduce thermal power ≥ 1% RTP within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$) prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The wordings in the Required Actions A.2 and A.3 which specify the magnitude of the setpoint reductions are proposed to be modified to account for the possibility that the limit for $F_Q^C(Z)$ is exceeded during a part-power surveillance.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) Reduce thermal power ≥ 1% RATED THERMAL POWER within 15 minutes for each 1% $F_Q^C(Z)$ exceeds the limit (Required Action A.1),

(2) Reduce the Power Range Neutron Flux-High trip setpoint ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1* within 72 hours (Required Action A.2),

(3) Reduce the Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required action A.1* within 72 hours (Required Action A.3), and

(4) Perform SR 3.2.1.1 (surveillance on $F_Q^C(Z)$) and SR 3.2.1.2 (surveillance on $F_Q^W(Z)$ prior to increasing the thermal power above the limit of Required Action A.1 (Required Action A.4).

The Completion Times associated with these Required Actions were not revised.

With the proposed change, when the limit for $F_Q^C(Z)$ is exceeded, thermal power will be limited to less than the surveillance power level required by Required Action A.1. The corresponding setpoints will therefore reflect this new thermal power limit. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, then thermal power will be limited to ≤ 74 percent RTP. Consequently, the new wording will require setpoint reductions of ≥ 26 percent since this is the amount by which the thermal power is limited below the RTP. The current Required Action wording would only require a setpoint reduction of ≥ 1 percent. In other words, the current requirement did not account for surveillance conducted at reduced power.

3.2.2 Changes to the Required Actions and NOTE for Condition B: $F_Q^W(Z)$ not Within Limit

The Required Actions for Condition B are different for RAOC and CAOC plants. Both are proposed to be revised in the improved F_Q TSs.

3.2.2.1 Proposed changes for RAOC plants

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced (Required Action B.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."

In addition, there was a NOTE with Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved F_Q TSs, pre-analyzed RAOC operating spaces, representing different levels of transient F_Q margin, will be in the COLR with characterized transient factors (T(Z) functions) which, in conjunction with the radial peaking factors, may be used to quantify the margin and ensure compliance with the LCO for future non-equilibrium operation. An RAOC operating space is a unique combination of an AFD operating space envelope and control rod bank insertion limits. In the unlikely event that none of the allowed RAOC operating spaces included in the COLR provides sufficient F_Q margin, minimum power level and AFD reductions will be required along with setpoint reductions. The magnitude of the reduction is included in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) *Implement a RAOC operating space specified in the COLR that restores* $F_Q^W(Z)$ *to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER and reduce AFD limits as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is changed to "Prior to increasing THERMAL POWER above the *limit of Required Action B.2.1.*"

The NOTE in Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "*Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1.*"

3.2.2.2 Proposed changes for CAOC plants

The changes to the TS for CAOC plants (TS 3.2.1C) are similar to those for the TS of RAOC plants (TS 3.2.1B). However, the current requirements for these two types of plants are slightly different.

When $F_Q^W(Z)$ is not within limits, the Required Actions were defined as follows:

(1) Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.1). The associated Completion Time is 4 hours.

(2) Reduce Power range Neutron Flux – High trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit (Required Action B.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that $F_Q^W(Z)$ exceeds limit (Required Action B.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.1.2 (Required Action B.4). The associated Completion time is "Prior to increasing THERMAL POWER above the limit of Required Action B.1."

In addition, there was a NOTE with Condition B which stated "Required Action B.4 shall be completed whenever this Condition is entered."

In the improved CAOC F_Q TSs, a new Required Action B.1.1 is proposed which requires implementation of a new CAOC operating space, specified in the COLR, which restores $F_Q^W(Z)$ to within its limits. A CAOC operating space is a unique combination of CAOC AFD band limits and control rod bank insertion limits. A more restrictive CAOC operating space limits the range of possible non-equilibrium power shapes more than the current CAOC operating space through a smaller AFD band and/or shallower control rod insertion limits. The smaller CAOC operating space results in more transient F_Q margin. Alternatively, instead of implementing a more restrictive CAOC operating space, thermal power may be limited to some maximum value as specified in the COLR.

The revised Required Actions are proposed to be defined as follows (changes are in *italics*):

(1) *Implement a CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits (Required Action B.1.1). The associated Completion Time is 4 hours.*

(2) *Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space (Required Action B.1.2). The associated Completion Time is 72 hours.*

Or, implement the following:

(1) *Limit THERMAL POWER to less than the RATED THERMAL POWER as specified in the COLR (Required Action B.2.1).* The associated Completion Time is 4 hours.

(2) Reduce Power Range Neutron Flux – High trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.2). The associated Completion Time is 72 hours.

(3) Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% *that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1* (Required Action B.2.3). The associated Completion Time is 72 hours.

(4) Perform SR 3.2.1.1 and SR 3.2.2.2 (Required Action B.2.4). The associated Completion Time is "Prior to increasing THERMAL POWER above the limit of Required Action B.2.1."

In addition the NOTE in Condition B is deleted and a NOTE is added to Required Action B.2.1 which states, "Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed *prior to increasing the THERMAL POWER above the limit of Required Action B.2.1.*"

3.2.3 Changes to Surveillance Requirements

The SRs are modified by a NOTE. The NOTE states the following, "During power escalation at the beginning of each cycle, thermal power may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."

The NOTE for the SR is proposed for elimination because it was considered to have been a source of confusion and can be interpreted differently by different utilities implementing the requirement.

3.2.4 Changes to Surveillance Requirements for $F_Q^C(Z)$: SR 3.2.1.1

The current SRs for $F_Q^C(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.1 requires verification that $F_Q^C(Z)$ is within its limits and it must be verified at the specified Frequency:

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 effective full power days (EFPD) thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In the improved F_Q TS, the second frequency is proposed to be revised to require verification within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period to perform the verification.

3.2.5 Changes to Surveillance Requirements for $F_Q^W(Z)$: SR 3.2.1.2

The current SRs for $F_Q^W(Z)$ are the same for both the RAOC and CAOC methodology. SR 3.2.1.2 requires verification that $F_Q^W(Z)$ is within its limits and it must be verified at the specified Frequency (same as $F_Q^C(Z)$):

(1) Once after each refueling prior to THERMAL POWER exceeding 75% RTP, and

(2) Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified; and

(3) Each 31 EFPD thereafter; or

(4) In accordance with the Surveillance Frequency Control Program.

In addition, there is a NOTE which modifies the SR as follows:

"If measurements indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$:

(1) Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or

(2) Repeat SR 3.2.1.2 once per 7 EFPD until either a., above, is met, or two successive flux maps indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has not increased."

The revised SR 3.2.1.2 modifies the first and second Frequency (items (1) and (2) above) and eliminates the NOTE.

The first Frequency is modified to be conducted following each refueling within [24] hours after achieving equilibrium conditions after thermal power exceeds 75 percent RTP. This change is justified based on multiple reasons:

- Initial startups are not expected to result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit since initial startups are slow and are tightly controlled due to startup ramp rate limitations and fuel conditioning requirements.

- Core power distribution measurements taken at low power (<50 percent RTP) to confirm that the core is loaded properly will provide ample indications that the core is operating consistent with the expectations.

- Surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75 percent RTP will ensure that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium conditions could be limiting.

- Power levels of ≤ 75 percent RTP are non-limiting for minimum transient $F_Q^W(Z)$ margin. Conducting surveillance within 24 hours after achieving equilibrium conditions after thermal power exceeds 75 percent RTP will assure verification prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

The second frequency is modified in the same way as SR 3.2.1.1 discussed earlier. It is proposed to require verification of $F_Q^W(Z)$ within 24 hours (instead of 12 hours) after achieving the equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period in which to confirm that $F_Q^W(Z)$ is within its limits given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The NOTE is eliminated, but the application of the penalty factor remains because it is in the $F_Q^W(Z)$ formulation in the improved methodology for F_Q Surveillance. The required penalty factor, referred to as R_j in the new formulation, will be included in the COLR and will be tied to a predicted decrease in the actual transient F_Q margin in the upcoming time period prior to the next performance of SR 3.2.1.2 rather than a measured increase in the value of $F_Q^C(Z)$/K(Z) over the previous time period. When the transient F_Q margin is predicted to increase, the COLR will indicate an R_j factor of 1.0 (i.e., no penalty). When the margin is predicted to decrease, the COLR will indicate an appropriate R_j factor based on the predicted margin trends.

3.3 ATTRIBUTES AND IMPROVEMENTS OF REVISED F_Q SURVEILLANCE METHOD

The following seven attributes/improvements were the response to RAI 13b, which asked for a discussion of the changes in the TSs and their relation to the improved methodology. This list provides a good summary of what is being attempted.

(1) The formulation for determining the measured transient $F_Q^W(Z)$ in RAOC plants has been revised to be less sensitive to the ability to predict the actual steady state axial power shape conditions where the surveillances are performed.

This is related to the use of the new T(Z) surveillance factor, which no longer includes the steady state axial power shape in the denominator, relative to the original W(Z) factor.

(2) Correction factors have been defined for the new F_Q surveillance equations which correct the results for any remaining errors associated with the actual plant conditions where the surveillance is performed, which may differ from the

predicted surveillance condition.[6] These factors are the $A_{XY}(Z)$ factors for RAOC plants and the $A_Q(Z)$ factors for CAOC plants, which have been added to the respective equations used to perform the $F_Q^W(Z)$ surveillance (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661). Two methods have been presented for representing the $A_{XY}(Z)$ and $A_Q(Z)$ factors. This includes the very simple assumption of unity for the factors, and a rigorous calculation of the factors at the specific conditions of each surveillance.

Comment [a4]: See comment a2 above.

(3) The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillances at part power conditions. This is done by moving the relative power term of the condition where the surveillance is performed out of the surveillance factors (i.e., T(Z) and W(Z)) and into the actual surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661-P). For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at the 50 percent RTP power level.

(4) Required Actions for cases where $F_Q^W(Z)$ exceeds the F_Q limit have been more rigorously defined and eliminate all reliance on "rules of thumb" that may not be strictly applicable in all situations. This is implemented through the possible application of new RAOC or CAOC operating spaces, or through the pre-defined limitations on power and AFD provided in the COLR, which are rigorously calculated using the standard NRC-approved analysis methods. These changes ensure that corrective actions taken in the rare circumstances when $F_Q^W(Z)$ exceeds the F_Q limit will be effective at restoring the necessary margin.

(5) The application of the burnup dependent penalty factor (R_j) to account for predicted decreases in the transient $F_Q^W(Z)$ margin during the next 31 EFPDs has been modified to apply to all surveillances, independent of the trends in measured $F_Q^C(Z)$ margin. This is implemented by incorporating R_j into the surveillance equations (see Equations 5-1, 5-2, 8-1, and 8-2 in WCAP-17661) and eliminating the conditional application of the penalty factor in the TS surveillances. This improvement corrects cases where the measured trend in $F_Q^C(Z)$ margin from the previous 31 EFPDs may be increasing, but the trend in $F_Q^W(Z)$ margin is decreasing due to changes in the surveillance factor data.

(6) Requirements to perform SRs 3.2.1.1 and 3.2.1.2 have been clarified in cases where $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed the F_Q limit. In any case where one or both parameters exceed the limit, both surveillances are required to be performed by the TS's Required Action.

(7) The F_Q surveillance TSs have been revised to rely on $F_Q^C(Z)$ surveillances during the initial power ascension after a refueling to demonstrate that continued power ascension is justified. The first $F_Q^W(Z)$ surveillance is not specifically required to be performed until 24 hours after the plant reaches equilibrium conditions at a power level greater than 75 percent RTP. This change recognizes the technical

[6] As discussed in Section 4.1, the NRC staff determined that the use of such factors, when less than unity, was not acceptable.

fact that the surveillance factors needed to perform an accurate $F_Q^W(Z)$ surveillance at very low THERMAL POWER levels are difficult to accurately calculate in advance of the surveillance, and that the most accurate $F_Q^W(Z)$ surveillances will be obtained from equilibrium conditions at greater than 75 percent RTP. The change is justified by the fact that the $F_Q^C(Z)$ surveillances confirm the core is behaving as predicted, and the initial power ascension after a refueling outage is performed in a slow, controlled manner, until the fuel is conditioned. The first $F_Q^W(Z)$ surveillance that is performed following a refueling justifies operation at 100 percent RTP over the next 31 EFPDs, under potential transient operation.

4.0 TECHNICAL EVALUATION

4.1 IMPROVED F_Q SURVEILLANCE FORMULATION

The rationale for the improved surveillance formulation was discussed in Section 3.1 and the new approach to defining $F_Q^W(Z)$ was summarized therein. Equation (4) represents the new formulation for RAOC plants and Equation (7) for CAOC plants. The derivation of these formulas in WCAP-17661 has been reviewed and found to be rigorous ~~with the exception of the penalty factor~~ $\cancel{R_j}$ which is added to take into account trends with burnup. In the following each of the important factors in Equation (4) for RAOC plants are considered. The evaluation for CAOC plants follows along similar lines.

Comment [a5]: The derivation of R_j is also rigorous.

The T(Z) factor is obtained as it always has been for the equivalent W(Z) {

}.

The PWROG proposed to introduce the $A_{XY}(Z)$ and $A_Q(Z)$ factors defined in Equations (6) and (8), respectively, to adjust for a change in radial peaking factor due to difference in power level and control rod insertion relative to the reference core condition. In practice, the $A_{XY}(Z)$ and $A_Q(Z)$ factors allow for a slight adjustment, usually a reduction, in the calculated $F_Q^W(Z)$, when the $F_Q^W(Z)$ surveillance is conducted {

}. This factor is evaluated in detail in Section 4.1.1 of this SE.

The use of the measured $F_{XY}(Z)$ rather than $F_Q(Z)$ is an important part of the new RAOC formalism. Examples of measurements from different reactors are shown in WCAP-17661 and although measurement of $F_{XY}(Z)$ can be problematic in planes where grids reside, this is not an issue, because grid plane regions are excluded from surveillance as noted below. Section 4.4 of WCAP-17661 notes that the regions where there are measurement exclusions continue to be:

- Lower core region, generally[7] from 0 percent to 15 percent inclusive
- Upper core region, generally[7] from 85 percent to 100 percent inclusive
- Grid plane regions, ±2 percent inclusive
- Core plane regions, within ±2 percent of the bank demand position of the control banks

The use of the uncertainty factor U_F to account for both instrumentation and manufacturing uncertainties was questioned (RAI No. 4) as it was not clear why a manufacturing uncertainty was needed. The RAI also questioned how the uncertainty in T(Z) was taken into account. The response to the RAI explains that the uncertainties used are conservative. The manufacturing (or engineering) uncertainty was originally introduced because the "measured" $F_Q(Z)$ in the formulation is a pin (i.e., fuel rod) power whereas the actual measurement is a fuel assembly power. The manufacturing uncertainty is needed to account for pin-to-assembly factors[8] that compensate for this difference. Since the measurement already accounts for actual

Comment [a6]: See comment a3.

[7] Per Footnote 4 on Page 3, the plant- or cycle-specific exclusion regions may be different.

[8] As noted in the RAI response, these pin-to-assembly factors account for the fact that the analytically derived pin factors are based on nominal design characteristics such as pellet enrichment, density, and

as-manufactured conditions, this is not important. Furthermore, since the definition of the T(Z) factor is based on bounding calculations, it is not necessary to introduce additional uncertainty for this factor. Hence, it is concluded that the approach to uncertainty in the improved methodology is sufficiently conservative.

The last factor in Equation (4) is a penalty that Westinghouse is suggesting and is related to the elimination of the NOTE for SR 3.2.1.2. The NOTE (see also Section 4.4) required certain actions take place when the maximum over Z of $F_Q^C(Z)$/K(Z)[9] increased relative to the previous surveillance. The concern at the introduction of this requirement was deviations between measured and predicted steady state power shapes due to integral fuel burnable absorber-induced power shift (also known as axial offset deviation, AOD) or crud induced power shift (CIPS) both of which occur slowly over time. WCAP-17661 explains how AOD has been resolved so that fewer cores now experience it and the instances of AOD are less severe.

CIPS is explained in the report and in the response to RAI No. 6. Like AOD, it is less of a problem than it once was. "Furthermore, CIPS develops slowly and has a characteristic [delta axial offset] signature making it relatively easy to detect." Hence, Westinghouse has proposed that, should CIPS occur, the effect on transient F_Q margin can be addressed in a timely fashion (with modifications to core models) and there is no need for the generic penalty as expressed in the NOTE for SR 3.2.1.2. There are several reasons specified by Westinghouse as to why this approach is reasonable and this review concurs with that reasoning.

The penalty that is proposed to be added (R_j) is to take care of downward trends in the F_Q margin that might be possible due not to anomalies like CIPS, but rather to ordinary changes caused by cycle depletion. Essentially the penalty added at the surveillance point j is related to the ratio of the $F_Q^W(Z')$ expected at the next surveillance point in the cycle (i.e., point j+1) to the $F_Q^W(Z')$ at point j, where the prime indicates that it is at the elevation where the margin to the limit is smallest. This calculation is done prior to the start of the cycle and the R_j values are ~~to be found~~ in the COLR. The minimum value that can be used is 1.0. This approach is reasonable and further justifies the elimination of the NOTE in SR 3.2.1.2.

CAOC plants will have the option of using Equation (7) to define the surveillance parameter. The major change is the introduction of the $A_Q(Z)$ factor. This factor is evaluated alongside $A_{XY}(Z)$ in Section 4.1.1.

4.1.1 Evaluation of A_{XY} and A_Q

WCAP-17661 proposes to implement, in the $F_Q{}^W(Z)$ surveillance formulation, new factors A_{XY} and A_Q for RAOC and CAOC W(Z) surveillances, respectively. The~~is~~ $A_{XY}(Z)$ factor is intended to normalize the T(Z) function used in the surveillance to the power distribution conditions present at the time of surveillance. The present evaluation is written based on the PWROG response to RAI 15, which included proposed revisions to WCAP-17661. The introduction to RAI 15 provides a succinct explanation of the purpose and derivation of the A factors.

Comment [a7]: The previous sentence discusses both $A_{XY}(z)$ and $A_Q(z)$. Beginning this sentence with the words, "This factor is intended to normalize the T(z) function…." is not clear, in particular since only T(z) is mentioned in the 2nd sentence. The 2nd sentence should be revised to: "The $A_{XY}(z)$ factor is intended to normalize the T(z) function…."

burnable absorber loading. The engineering uncertainty addresses the effects of variations in the as-built fuel pellet from such nominal values.

[9] K(Z) is a function that defines the axial dependence of the acceptable value of F_Q.

WCAP-17661, as revised, sets forth two methods for the A_{XY} and A_Q factors. Method 1 is to assume that it is always unity; in other words, surveillances would be performed without correcting for possible deviations from the reference condition, for which the T(Z) or W(z) functions are determined. Method 2 is to perform on-line calculations.

Comment [a8]: This sentence discusses both the $A_{XY}(z)$ and $A_Q(z)$ functions, therefore, the end of the sentence should be revised to state: "... for which the T(z) or W(z) functions are determined."

Several considerations justify an allowance to keep the RAOC surveillance uncorrected. First among these is the fact that the vast majority of surveillances are conducted in a Hot Full Power (HFP), All Rods Out configuration, such that there would be little deviation from the reference condition. Stated differently, in most cases, the A_{XY} factor would seldom deviate from unity, and deviations are usually expected to be minor. Second, the existing methodology does not include this correction. Third, PWROG provided, in response to RAI 15.e, several tables were provided for a demonstration plant with several successive surveillances completed slightly above 80-percent RTP, with 14-percent D-bank control rod insertion. These tables show that the A_{XY} factor removes a small amount of conservatism from the uncorrected surveillance, meaning that, in these conditions, a unity-value A_{XY} is conservative. The response to RAI 15.e., included~~PWROG also provided~~ a table illustrating what an A_{XY} correction would be if the plant were perturbed to a lower power level, close to 50-percent RTP, where the A_{XY} correction at the limiting margin elevation corrects an approximately { } of actual F_Q margin. The data provides an indication that the A_{XY} correction is usually minor, and that it increases in magnitude as the core begins to deviate more from the reference condition. Based on the PWROG~~-~~demonstration that the A_{XY} factor is generally a minor correction to the $F_Q^W(Z)$ RAOC surveillance, the NRC staff determined that Method 1 for determining A_{XY} is an acceptable way to correct for surveillance~~off-reference~~ conditions that are different than the reference condition.

If the A_{XY} or A_Q factor is implemented using Method 2, it will be calculated using the methods listed in the response to RAI 15.c, and subject to the constraints discussed in the response to RAIs 15.b and 15.d. The response to 15.b includes references to the currently acceptable TRs describing methods for calculating the A_{XY} and A_Q factors. Additional, newer methods may also be used, provided they are specifically found to be acceptable by the NRC staff for doing so.

A_{XY} is, by definition, a ratio of {

} As such, the response to RAI 15.b describes several items that may cause discrepancies. The discrepancies arise because the T(Z) function is based on the original core design, whereas the A_{XY} numerator will reflect properties of the actual core, such as actual inventory of reconstituted fuel assemblies and the use of an actual previous cycle shutdown burnup instead of the burnup window used in the original design. The response to RAI 15.b also indicates that the same discrepancies would be included in the A_{XY} denominator, or the $F_{XY}(Z)$ function for the surveillance condition, meaning that the ratio remains valid despite the difference between the as-designed and as-operated conditions. In addition,

the response to RAI 15.b., ~~PWROG~~ stated that the depletion calculations for the as-operated conditions would be performed in the same manner as the original nuclear design model. These considerations ensure that the A_{XY} factor is a valid proportion to use when scaling the T(Z) function to correct~~return values appropriate~~ for the surveillance conditions. Limitation 2 in Chapter 5 of this SE addresses requirements to use NRC-approved core design or surveillance methods to calculate the A_{XY}, and to perform the calculations consistent with the original core design model.

In large part, the A_Q factor is utilized~~operates~~ in CAOC – ~~T~~W(Z) surveillance the same as A_{XY} is utilized~~does~~ in the RAOC surveillance, with a noteworthy difference. The A_Q factor was more likely to be greater than unity by a significant amount, particularly at rodded core elevations. Therefore, in the response to RAI 15.a, PWROG proposed two additional constraints were proposed on the use of a unity value A_Q, i.e., Method 1, to correct fo~~complete off-nominal~~ surveillance conditions that are different from the reference condition: such surveillance is precluded if the current axial offset is more than ±1.5-percent different than~~of~~ the target value, or if Control Bank D is inserted to the elevation of anticipated limiting $F_Q^W(Z)$ margin. Subject to this constraint, which is also reflected in Limitation 2 in Chapter 5 of this SE, the NRC staff determined that the use of methods 1 and 2 to calculate the A_Q factor for the CAOC-W(Z) surveillance is acceptable, as the constraints will ensure that an explicitly calculated A_Q factor will be used when off-reference conditions would result in an $F_Q^W(z)$ surveillance that is unlikely to be sufficiently conservative.

Comment [a9]: The response to RAI 15.a discussed the potential use of Method 1 for A_Q (i.e., $A_Q(z)=1.0$) if "surveillance specific" W(z) factors are provided for a specific core condition different from the normal reference surveillance condition for a CAOC plant (i.e., all rods out, 100% RTP). If a utility identifies in advance that they want to perform a Surveillance at a specific condition (for example 80% RTP, with D-Bank inserted 20% near the beginning of the cycle), W(z) factors can be generated specific to that surveillance condition using the NRC approved CAOC methodology and added to the COLR. This methodology would provide an accurate result without explicitly requiring the calculation of $A_Q(z)$ using Method 2. Currently, the Draft Safety Evaluation does not specifically discuss the potential use of Method 1 when surveillance specific W(z) factors are used. Method 2 $A_Q(z)$ calculations would be required to be performed for such a Surveillance. Therefore, a statement should be added to Sections 4.1.1 and 5.2.3 which specifically approves the use of Method 1 for $A_Q(z)$ when a surveillance is performed at conditions different from the normal reference condition using surveillance specific W(z) factors that are consistent with the conditions of the surveillance.

4.1.2 Conclusion Regarding Improved Surveillance Formulation

In summary, the new approach for the surveillance parameter $F_Q^W(Z)$ for both RAOC and CAOC plants is valid and eliminates a non-conservatism in the previous approach for RAOC plants. Thus, the revised $F_Q^W(Z)$ surveillance provides improved assurance that an implementing facility will be operated within the initial conditions assumed in the safety analyses, consistent with the requirements set forth in 10 CFR 50.36(c)(3). It is therefore acceptable as part of the surveillance methodology.

4.2 REVISIONS TO REQUIREMENTS UNDER CONDITION A OF TS 3.2.1B AND 3.2.1C

This change[10] proposes to revise the setpoint reductions that are required when $F_Q^C(Z)$ is not within limits. Specifically, Required Actions A.2 and A.3 will be revised replacing "1 percent for each 1 percent $F_Q^C(Z)$ exceeds limits" with "1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."

The proposed new wording will require greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(Z)$ exceeds its limits. For example, if the surveillance thermal power is 75 percent and $F_Q^C(Z)$ exceeds its limit by 1 percent, thermal power will be limited to ≤ 74 percent RTP. This new wording will require setpoint reductions of ≥ 26 percent, since this is the amount by which the thermal power is limited below the RTP. In other words, both Neutron Flux – High trip setpoints and Overpower ΔT trip setpoints will require setpoint reductions of ≥ 26 percent. This is different from the current wording which requires a setpoint reduction of ≥ 1 percent.

[10] See Table 2 for a list of all changes.

The current wording implicitly assumed that the surveillance is always performed at full power. The revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance and appropriately defines the setpoint reductions.

The proposed revision to the Required Actions A.2 and A.3 addresses an issue with the actions for surveillance conducted at part-power. These changes will require an appropriate conservative reduction of the setpoints assuring that the limits on $F_Q^C(Z)$ assumed in the accident analyses remain valid. With the change, the requirements are appropriately worded for implementation since they are associated with~~connected to~~ the power level reductions defined in Required Action A.1.

The NOTE to Condition A is revised. It previously stated that "Required Action A.4 shall be completed whenever this Condition is entered." This NOTE was considered confusing, given the changes being proposed for SR 3.2.1.1 and 3.2.1.2. The revised NOTE states: "Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling." This revision makes the NOTE consistent with the changes in Required Actions and SRs, and it resolves the issue described above by making the NOTE more explicit.

These changes are not expected to cause any new accident or increase the likelihood of considered accidents. Rather, the changes are expected to reduce the consequence of accidents by assuring that $F_Q^C(Z)$ remains within the bounds assumed in the accident analyses. The proposed remedial actions are conservative compared to the current actions and can contribute to an improved margin of safety. Based on these considerations, the NRC staff determined that the proposed revisions are acceptable, insofar as they are consistent with the requirements established in 10 CFR 50.36(c)(2) for remedial actions, which may be established for conditions when an LCO is not met.

4.3 REVISIONS TO REQUIREMENTS UNDER CONDITION B OF TS 3.2.1B AND 3.2.1C

The newly added Required Actions replace prior actions requiring reduction of the AFD limits by one percent for each percent that $F_Q^W(Z)$ exceeded its limits, followed by a requirement to reduce thermal power level if the former Required Action does not restore adequate $F_Q^W(Z)$ margin. Administratively, licensees do not implement~~have eliminated~~ the AFD required action and are presently required to reduce power if $F_Q^W(Z)$ exceeds its limits, in response to NSAL 09-5.

The revisions to the Required Actions associated with $F_Q^W(Z)$ exceeding its limits address the concern that the AFD reductions currently prescribed by TS are not sufficiently conservative to restore adequate margin to the heat flux hot channel factor. The existing TS Required Actions are based on assumptions that (1) the $F_Q^W(Z)$ violation occurs when the axial peak is outside the core mid-plane, and (2) constraining the power peaking in the core to its axial mid-plane region will restore the necessary margin. The PWROG notes that $F_Q^W(Z)$ violations are uncommon, and that when they occur, they do so more frequently outside the core mid-plane. However, the existing Required Action does not restore margin if the $F_Q^W(Z)$ violation occurs near the core mid-plane. To resolve the issue, the TR introduces a ROS or COS, depending on the power maneuvering control strategy, that can constrain AFD limits as before, but also

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introduces new T(Z) functions and possibly control rod insertion limits to further constrain maneuvering capability and restore the necessary margin. Rather than being based on assumptions that constraining the AFD limits yields the necessary margin, the new operating spaces are based on NRC approved RAOC or CAOC~~maneuvering~~ analys~~ie~~s~~θ~~ methodologies.

4.3.1 <u>Required Actions B.1.1 and B.1.2; Deletion of NOTE Requiring SRs 3.2.1.1 and 3.2.1.2 Whenever Condition B is Entered</u>

A new Required Action B.1.1 was included, which requires licensees to "Implement an RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits" whenever $F_Q^W(Z)$ is determined to be not within the limits. Based on the NRC staff review, PWROG also proposed to add the associated Required Action B.1.2, for instances in which the implementation of a new operating space requires control rod motion. It states "Perform SR 3.2.1.1 and SR 3.2.1.2 [verification, respectively, that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits] if control rod motion is required to comply with the new operating space."

An ROS or COS is a unique combination of AFD limits and control bank insertion limits. The operating spaces are pre-analyzed using the approved methodology and included in the COLR. The number of operating spaces that will be included in the COLR will be determined by the utility in conjunction with the core designer. WCAP-17661 presents example calculations providing the thermal power limit and the required margin reductions for different $F_Q^W(Z)$ margin improvements for a RAOC plant (Table 6-10 for ROS) and thermal power limits for different $F_Q^W(Z)$ margin improvements for a CAOC plant (Table 9-7 for COS). For the RAOC plants, in the improved methodology the margin improvement can be confirmed using the T(Z) factors. Previously, it was presumed that the AFD limits would provide the necessary margin improvement.

As documented in the submitted TR, PWROG proposed to delete the NOTE in Condition B, which required the performance of SR 3.2.1.1 and SR 3.2.1.2 whenever the Condition was entered. This NOTE required verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. The deletion of this NOTE was the subject of Topics (a) and (c) under RAI 5, which sought to address the following issues:

- The use of a different operating space to gain margin improvement was considered an appropriate application of the new methodology presented. However, the NRC staff determined that situations may occur where a different rod insertion limit may result in~~be needed associated with~~ some control rod movement. Withdrawal of a control rod could potentially increase the $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values (RAI 5a).

- Inclusion of the requirements to perform SR 3.2.1.1 and SR 3.2.1.2 may be necessary to assure that the changes in $F_Q^C(Z)$ and $F_Q^W(Z)$ remain acceptable assuring that the margin is being maintained (RAI 5c).

In responding to this RAI, PWROG agreed to modify the proposed Required Actions for Condition B of TS 3.2.1B and 3.2.1.C. Specifically, to address the above issues, PWROG agreed to add Required Action B.1.2, with a Completion Time of 72 hours. This new Required Action will require the completion of SRs 3.2.1.1 and 3.2.1.2 in the event that implementation of a new operating space results in the need to move the control rods to comply with a new rod insertion limit.

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Completion of Required Action B.1, as originally proposed, may have resulted in a need to move the control rods. The measured $F_{xy}(Z)$ peak can occur adjacent to or in an assembly containing an inserted control rod and the withdrawal of the control rod could potentially increase the resulting $F_Q^C(Z)$ and $F_Q^W(Z)$ measured values. Also, a revision to the allowed AFD band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion in order to obtain and maintain the AFD within the allowed operating band.

With the addition of Required Action B.1.2 (the current Required Action B.1 becomes B.1.1) to perform SR 3.2.1.1 and 3.2.1.2 will provide assurance that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits or appropriate actions are taken. Performing these surveillances will also provide the operators assurance that the margin is being maintained. A 72-hour completion time is provided to ensure that the plant has time to restore equilibrium conditions in the event that control rod motions result in transient conditions.

In Topic (b) of RAI 5, the NRC staff determined that, to remain in the operating space defined by Required Action B.1, operators would need to have a clear understanding that the margin improvement is being maintained. Additional information for the operator may be needed to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary. The NRC staff requested that PWROG justify why a tabular presentation of the margin improvement as a function of the axial position or some other scheme in the COLR would not be required. In its response, PWROG stated that the margin can be determined by applying the new surveillance factors associated with the revised operating space to the power distribution measurement. Additionally, the PWROG noted that $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances would now be required in the event that implementation of a new operating space requires control rod motion. Thus, PWROG stated that performance of the SRs would provide the necessary margin confirmation. The NRC staff agrees with the PWROG response, since the concern was related to the implementation of new operating spaces in conjunction with control rod motion, which would require performance of ~~new surveillances~~ SR 3.2.1.1 and SR 3.2.1.2.

Topic (d) of RAI 5 addresses the actions that will be taken by the operators to remedy potential violations of the newly implemented operating space associated with Required Action B.1. The PWROG identified other TS Required Actions and SRs that would apply in such a situation, particularly with regard to control rod insertion limits and position. Because the potential for violation of the core operating limit parameters for an operating space can be addressed through existing TS Required Actions and SRs, the NRC staff determined that PWROG addressed the concern indicated in RAI 5d acceptably.

The improved methodology allows for the use of new operating spaces, as defined in the COLR. The addition of Required Action B.1.2 assures that for situations involving control rod movement, ~~surveillance~~ SR 3.2.1.1 and SR 3.2.1.2 will be conducted to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits. Based on the review described above, the NRC staff determined that the proposed Required Actions B.1 are acceptable.

4.3.2 Required Action B.2 and Limitation on Thermal Power

The improved TSs define a new Required Action B.2 which includes four actions (B.2.1, B.2.2, B.2.3, and B.2.4). If the RAOC or CAOC operating spaces defined in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Actions B.2 are entered. The actions

involve reducing the thermal power to less than the thermal power specified in the COLR along with reduction of the setpoints. For more explicit presentation of the changes and associated justifications, see Table 2.

The issues addressed in the review of these changes related to the change of the thermal power level. As noted in WCAP-17661-P, the reductions in the thermal power levels evaluated and included in the COLR ~~will be limited to three or less. An individual utility may opt for additional evaluation levels.~~ If the required margin improvement exceeds the level of pre-analyzed thermal power limits, then the option is to limit the thermal power to < 50 percent RTP. The 50 percent RTP applies to all Westinghouse plants that implement this Topical Report and no plant-specific evaluations are involved. However, in response to RAI 7, PWROG stated that the 50 percent value is consistent with the required power reduction associated with other power distribution surveillances (e.g., $F^N_{\Delta H}$), and agreed to add paragraphs addressing this scenario in the BASES.

The need to limit thermal power to < 50 percent RTP is expected to be a rare occurrence. However, such a situation may indicate a ~~serious~~ core anomaly and is a useful discussion in the TS BASES for understanding of the operating personnel. Since the 50 percent value is consistent with the power reduction associated with other peaking factor surveillances the NRC staff finds the proposed Required Action B.2 acceptable for the purposes of this TR.

The final required THERMAL POWER limit provided in the COLR~~-~~input supporting Required Actions B.2 for each ROS or COS must be < 50 percent RTP. Even though the final power reduction amount is fixed, it is appropriate for inclusion in the COLR and not the TS, because the required amount of margin improvement at which this power reduction becomes necessary may vary from cycle to cycle. This is a limitation on the NRC staff approval of the TR, as discussed in Section 5.3 of this SE.

4.4 REMOVAL OF NOTES FOR F_Q SURVEILLANCE

Two notes in the SRs are proposed to be removed. The first note, applied to both SR 3.2.1.1 and 3.2.1.2, required obtaining the power distribution map for measuring $F_Q^C(Z)$ and $F_Q^W(Z)$ in equilibrium conditions during power escalation at the beginning of each cycle[11]. The second NOTE applies to SR 3.2.1.2 and requires multiplication of $F_Q^W(Z)$ by a factor and increased surveillance under certain conditions.

The first NOTE has been a source of confusion and was interpreted differently by various utilities. From section 3.2.4 of the topical report it appears that it was understood that a determination of $F_Q^C(Z)$ had to be obtained prior to exceeding 75 percent RTP. It is also considered that equilibrium conditions are not necessary for obtaining the power distribution map. The removal of the first NOTE removes any requirement for obtaining equilibrium conditions during the first power distribution map measuring $F_Q^C(Z)$. $F_Q^C(Z)$ is required to be verified after each refueling prior to exceeding 75 percent RTP in the first part of the frequency. ~~The need for requirements for plant condition in the TS instead of the current NOTE was considered.~~

[11] The first note stated, "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which [*sic*] a power distribution map is obtained."

In consideration of the removal of the first NOTE, the first Frequency for SR 3.2.1.1 no longer includes a definition of the applicable plant condition. However, *equilibrium conditions* are defined for other surveillances. Given that *equilibrium conditions* are defined for the conduct of surveillance, the NRC staff determined that a definition of *equilibrium condition* should be retained in the BASES discussion. The proposed change to the Bases associated with the SRs, to remove the definition of the *equilibrium condition*, can lead to confusion in implementing the surveillance and using the surveillance results. In its response to RAI 9, PWROG proposed define *equilibrium conditions*, for the purposes of SRs 3.2.1.1 and 3.2.1.2, as "...achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance." This definition was added to the BASES for both SRs. Since PWROG agreed to define the plant condition in the BASES, the NRC staff determined that the disposition regarding the plant condition for these surveillances was acceptable.

The effect of the removal of the first NOTE on SR 3.2.1.2 is that $F_Q^W(Z)$ will not be required to be determined until after equilibrium conditions are achieved after exceeding 75 percent RTP instead of before exceeding 75 percent RTP following a refueling outage as currently specified. For further detail regarding the change to the time the first $F_Q^W(Z)$ surveillance is required, refer to Item 7 in Section 3.3, and to Section 4.7, of this SE.

The second NOTE defined the penalty factor for $F_Q^W(Z)$. In the improved methodology, the penalty factor is embedded in the methodology and a separate penalty factor is not applicable. In addition, it is understood that an increasing trend in $F_Q^W(Z)$ measurement is not indicative of future margin trends and accordingly, increased surveillance based on an increasing trend may not be desired. Additional review considerations regarding the deletion of this NOTE appear in Section 4.6 of this SE.

Based on the considerations discussed above, the NRC staff determined that the proposed deletion of the NOTEs associated with F_Q surveillance was acceptable. In summary, the deletion of the first note will eliminate confusion and inconsistency among implementing licensees, the *equilibrium condition* required for the surveillances will be defined in the BASES, and the penalty factor associated with the second NOTE is now embedded in the methodology. The NRC staff also notes that revisions made to the NOTES in Condition A and Required Action B.2 clarify some of the conditions under which SRs 3.2.1.1 and 3.2.1.2 are necessary, further obviating the need for these NOTES.

4.5 REVISION OF SECOND SURVEILLANCE FREQUENCY FOR SRS 3.2.1.1 AND 3.2.1.2

Verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits (SR 3.2.1.1 and SR 3.2.1.2) includes a second requirement in the Frequency column of "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." This requirement assures verification of the F_Q limits whenever a significant increase of thermal power level has occurred.

The increase in the time interval for completing the required surveillance from 12 to 24 hours was based on the argument that some plant TSs have used the 24-hour time interval without any adverse effects and there is an extremely small likelihood of limiting power shapes or limiting design basis events occurring during this period.

The response to RAI 8 provided additional technical justification as follows:

- Westinghouse fuel conditioning guidelines require at least { } cumulative hours of operation at a steady state power level in the last { } period in order for the fuel to be considered fully conditioned. The type of load-follow maneuvers that could result in heat flux hot channel factors that may challenge the F_Q limits will not take place before the surveillance is completed at 100 percent RTP.

- Prior to this surveillance, $F_Q^C(Z)$ has already been measured at least once at a reduced power level providing assurance that increasing power up to the next plateau will not exceed the F_Q limits and that the core is behaving as designed.

Based on these considerations identified in the response to RAI 8, the NRC staff determined changing the second surveillance time from 12 hours to 24 hours is acceptable. A discussion of the reasons for allowing 24 hours to complete F_Q surveillance is included in the Bases. Since the disposition for the increased completion time is based on Westinghouse fuel conditioning guidelines, adherence to such guidelines is a limitation of the NRC staff approval of the TR, as discussed in Section 5.1 of this SE.

Comment [a10]: See Attachment 1

4.6 <u>DELETION OF NOTE IN SR 3.2.1.2</u>

The NOTE in SR 3.2.1.2 required increasing the ~~f~~Frequency to once per 7 EFPD for certain conditions until these conditions are satisfied. The intent of the NOTE in the current TS is to account for potential increases in $F_Q^W(Z)$ between surveillances. It required application of the greater of a 1.02 factor or a factor specified in the COLR whenever the measurement indicated that the maximum value of $F_Q^C(Z)$/K(Z) has increased. Alternatively, SR 3.2.1.2, "Verify that $F_Q^W(z)$ is within limit," is repeated once per 7 EFPD until $F_Q^W(Z)$ is within limit with the penalty factor applied or two successive flux maps indicate that $F_Q^C(Z)$/K(Z) has not increased.

The justification for eliminating the NOTE is that the required penalty factor is part of the $F_Q^W(Z)$ formulation in the new methodology. A penalty factor R_j is introduced and will be included in the COLR. The magnitude of the penalty factor is calculated based on the predicted margin trends and no additional assumptions or considerations are necessary.

The use of the new methodology and the built-in penalty factor has a number of advantages: (a) it will better capture the expected trend in the margin avoiding any lag in the application as was the case previously, (b) it avoids application of an arbitrary 2-percent minimum penalty, and (c) it eliminates the need for more frequent surveillance.

The issue addressed in this change is that past measurement trends are no longer being used (RAI 6b). This may be justified because, as stated in WCAP-17661, past measurement trends of $F_Q^C(Z)$/K(Z) may or may not be indicative of future margin trends.

The response to RAI 6 provided the following additional information:

- In some situations, measured trends in $F_Q^C(Z)$ may not always be indicative of the same margin trends in the measured $F_Q^W(Z)$. An example of such a situation is when the axial

power distribution of the core is in transition from a cosine shape to a flattened saddle shape.

- During the initial onset of CIPS, a similar decreasing trend for both $F_Q^C(Z)$ and $F_Q^W(Z)$ may not necessarily occur. An increasing trend in the margin of $F_Q^C(Z)$ may occur due to a decrease in the radial peaking ($F_{XY}(Z)$) in the affected elevation of the highest power assemblies due to preferential accumulation of boron-containing crud there and the AFD being closer to zero or slightly negative for onset of CIPS. The trend in $F_Q^W(Z)$ is driven largely by the T(Z) or W(Z) surveillance factors.

Based on its review of the additional information provided in the response to RAI 6~~by PWROG~~, the NRC staff determined that (1) it is an improvement that past measurement of $F_Q^C(Z)$ will no longer be used and (2) the NOTE in SR 3.2.1.2 for more frequent surveillance based on past measurements of $F_Q^C(Z)$ should no longer be required. The use of the penalty factor in the methodology to determine $F_Q^W(Z)$ is appropriate in assuring that this parameter is within limits. Thus, the NRC staff determined that the deletion of the NOTE, combined with the inclusion of a penalty factor in the $F_Q^W(Z)$ surveillance formulation is acceptable. The surveillance provides an acceptable confirmation that the power distribution remains within analyzed limits, including in instances where the surveillance indicates trends of reducing margin to $F_Q^W(Z)$ limits.

4.7 CHANGE IN FREQUENCY OF SR 3.2.1.2 DURING POWER ESCALATION

The current SRs for $F_Q^W(Z)$ (SR 3.2.1.2) are the same for both the CAOC and RAOC versions of the current F_Q Surveillance. The first part of the three-part surveillance frequency required assuring $F_Q^W(Z)$ within limits "once after each refueling prior to THERMAL POWER exceeding 75% RTP." This requirement is being changed to state that $F_Q^W(Z)$ must be verified to be within the limits following each refueling within 24 hours after achieving equilibrium conditions after THERMAL POWER exceeds 75 percent RTP.

The intent of this SR is to ensure that the F_Q will be maintained during future non-equilibrium operation within the allowed operating space.

The surveillance factors needed to perform an accurate $F_Q^W(Z)$ margin assessment at a very low power are difficult to generate without the advance knowledge of the expected operating power profile during the power ascension. The improved methodology presented in the submittal mitigates this concern partly. Conducting the surveillance after exceeding 75 percent power, ensures that surveillance will be conducted with appropriate steady state peaking factors measured at or near the peak power level and core conditions where future non-equilibrium conditions have the potential for challenging the fuel limits.

In this approach, power ascension within acceptable power peaking limits is assured, based on $F_Q^C(Z)$ surveillance. The F_Q surveillance equations have been changed to appropriately correct for the performance of surveillance at reduced power conditions. For power levels less than 50 percent RTP, the F_Q limits are correctly evaluated at 50 percent RTP power level.

In addition, the following considerations apply, as stated in the submittal:

- Limitations on ramp rates and fuel conditioning requirements assure that initial startups following a refueling are slow and tightly controlled. As discussed in response to RAIs, Westinghouse fuel conditioning guidelines require at least { } cumulative hours of operation at a steady state power level in the last { } period in order for the fuel to be fully conditioned. With this procedure, following a refueling, non-equilibrium power shapes that may challenge the F_Q limits, are not expected to occur.

- Core power distribution measurements and physics testing performed at low powers (<50 percent RTP) confirm that the core is loaded properly and is operating consistent with expectations.

The other issue relating to this change is the 24 hours for conducting the surveillance after achieving the equilibrium conditions after THERMAL POWER exceeds 75 percent RTP. Because of fuel conditioning requirements, more than 24 hours will be spent at a steady state power level before the type of load follow maneuvers are permitted that may result in heat flux hot channel factors that may challenge the F_Q limits.

Based on the considerations discussed above, the NRC staff determined that the technical justification for changing the first frequency of SR 3.2.1.2 is acceptable. Primarily, the power ascension for the first startup of the cycle following a refueling is tightly controlled, such that $F_Q^C(Z)$ surveillance provides reasonable assurance that the core power distribution remains within analyzed limits. Further, the ability to perform an accurate $F_Q^W(Z)$ margin assessment is substantially improved once steady-state operation above 75-percent RTP is achieved. Since the justification for the modified SR is based in part on Westinghouse fuel conditioning guidelines, implementing licensees must adhere to such guidelines in order to implement this TR. This is a limitation of the NRC staff approval of this TR, as discussed in Section 5.1 of this SE.

Comment [a11]: See comment a10 above.

4.8 CHANGES TO BASES

For the changes to RAOC and CAOC F_Q TSs (TS 3.2.1B and TS 3.2.1C), corresponding changes were made to the TS BASES. WCAP-17661-P provides the changes to the BASES to make them compatible with the changes made to the TSs. The changes to the BASES were reviewed and were discussed as part of the RAIs. The conclusion of the review was that additional discussions or clarifications for some aspects would be beneficial and provide improved clarity and understanding of the requirements in the TSs.

Additional discussions in the following areas were added in the BASES as part of the review of WCAP-17661:

1. Under the change for both RAOC and CAOC plants, Required Actions are now different for Conditions A, $F_Q^C(Z)$ not within limit, and B, $F_Q^W(Z)$ not within limit. When $F_Q^C(Z)$ is not within limit, reduction of THERMAL POWER is required along with reduction of setpoints and performance of SR 3.2.1.1 and SR 3.2.1.2. Whereas, when $F_Q^W(Z)$ is not within limits, two alternative actions may be applicable as discussed in the response to RAI 1. The first alternative action is included in Required Action B.1.1. This Required Action first requires implementation of a different operating space. If an appropriate operating

space cannot be implemented, then reduction of THERMAL POWER and setpoints and performance of SR 3.2.1.1 and SR 3.2.1.1 are required as an alternative. These aspects are discussed in the "Actions" section of the Bases.

The changes to the Condition B Required Actions, when $F_Q^W(Z)$ exceeds limits is intended to avoid THERMAL POWER reduction through implementation of a different operating space (Required Action B.1). However, when both $F_Q^C(Z)$ and $F_Q^W(Z)$ are not within limits, Required Action for $F_Q^C(Z)$ will require reduction of THERMAL POWER. The corresponding evaluation and action for $F_Q^W(Z)$ may be different. For example, Condition A ($F_Q^C(Z)$ not within limit) requires reduction of THERMAL POWER ≥ 1 percent for each 1 percent $F_Q^C(z)$ exceeds limit, but Condition B ($F_Q^W(Z)$ not within limit) may require reduction of THERMAL POWER as evaluated and set forth in the COLR.[12] As explained as part of the response to RAI 1, if both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, Required Action A.1 will be completed first due to the 15-minute Completion Time. Once the power level is reduced below that specified by Required Action A.1, the current operating peak power density will be restored to less than the value assumed in the safety analysis. As noted in the response to RAI 1, this Required Action may not ensure that the $F_Q^W(Z)$ limit is met.

The new Required Actions for Condition B are proposed to either implement a new operating space or a reduction in THERMAL POWER, and are required in order to ensure compliance with the $F_Q^W(Z)$ limit during future operation under transient conditions.

As a follow-up to the RAIs, these aspects are discussed and the BASES, which contain the clarifications regarding implementation of the proposed changes under different scenarios of $F_Q^C(Z)$ and $F_Q^W(Z)$ violations.

2. Under the proposed change, the new Required Action B.1.1 requires implementation of a RAOC/CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ within its limits. If control rod motion is needed as a result of entering Condition B and performing Required Action B.1.1, the fundamental measured power distribution will change as a result. As stated in response to RAI 5, in some cases, a revision to the allowed AFD band associated with implementing Required Action B.1.1 could result in either control rod withdrawal or insertion, in order to obtain and maintain the AFD within the allowed operating band. If the implementation of Required Action B.1.1 results in a need to move control rods, SR 3.2.1.1 and SR 3.2.1.2 should be performed to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within limits. This is addressed through the addition of Required Action B.1.2 and associated discussions are included in the Bases.

3. Under the proposed changes, if the operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then THERMAL POWER must be reduced to less than the thermal power specified in the COLR. Also, AFD limits must be

[12] While Tables 6-10, 9-7, C-7, and F-7 in the TR show examples where the margin was defined in 5 percent decrements, the NRC staff understands that other decrements may be used, provided such decrements are analytically supported.

reduced by the amount specified in the COLR. ~~As a practical matter, the number of discrete reduced power level evaluations included in the COLR is limited to three or less (an individual utility may opt for additional evaluation levels).~~ If the required margin improvement exceeds the level of any pre-analyzed thermal power limits, the COLR will specify that the thermal power is limited to <50 percent RTP.

The requirement to reduce thermal power to <50 percent RTP is discussed in the BASES as part of the review of the submittal to ensure completeness of the actions required and to provide clear guidance to the plant operators.

4.9 INTERFACES WITH OTHER REQUIREMENTS

In assessing the changes to TS 3.2.1B and TS 3.2.1C, the interface of these requirements with other TS requirements was reviewed. The intent was to determine whether changes in these requirements may necessitate changes in other requirements.

Based on the review, two interfacing aspects were identified:

1. It was noted that TS 3.2.1A, Heat flux Hot Channel Factor ($F_Q(Z)$ (CAOC $-F_{xy}$ Methodology)) is included for some plants. But, the concepts used in TS 3.2.1C are not used for TS 3.2.1A, i.e., TS 3.2.1A is not modified to use a different operating space and avoid reduction in THERMAL POWER. This issue was the topic of RAI 11.

2. TS 3.2.4, "Quadrant Power Tilt Ratio (QPTR)," which provides limits and associated SRs for QPTR, may be affected by the proposed changes. The QPTR limits ensure that nuclear enthalpy rise hot channel factor ($F_{\Delta H}^N$) and $F_Q(Z)$ remain below their limiting values by preventing an undetected change in the gross radial power distribution. The QPTR limit of 1.02, at which corrective action is required, provides a margin of protection for both the departure from nucleate boiling ratio and linear heat generation rate contributing to excessive power peaks resulting from X-Y plane power tilts. Assurance is needed that the margin of protection is not being lost or that adequate margin of protection will still be maintained. This issue was the topic of RAI 12.

The response to RAIs 11 and 12 provided the following clarifying information:

1. The Required Actions in TS 3.2.1A are more conservative than those in proposed TS 3.2.1C. This is because TS 3.2.1A effectively treats all cases where the $F_Q(Z)$ limit is exceeded as if the plant is currently operating with a peak power density in excess of what is assumed in the safety analysis. The plants that have implemented TS 3.2.1A do not have to implement proposed TS 3.2.1C, since the resulting surveillance required by TS 3.2.1A is valid and conservative.

2. The implementation of a different operating space in the event that the performance of an $F_Q^W(Z)$ surveillance determines that the F_Q limit is not met would not significantly affect the indicated QPTR on the excore detector, nor would it affect the actual in-core power distribution symmetry.

3. Addition of a Required Action of performing SR 3.2.1.1 and SR 3.2.1.2, with a Completion Time of 72 hours, when a new operating space is implemented, which

results in control rod motion, will provide the requisite margin of protection. With this addition, the margin to safety analysis limits will be determined and confirmed after the implementation of a new operating space, including the effects of any existing QPTR. Once this is done, the same initial conditions are established with respect to the continued applicability of TS 3.2.4, as would otherwise have been present before the new operating space was implemented.

4.10 SUMMARY OF KEY REVIEW TOPICS

Based on the review described above, the NRC staff determined that the reformulated F_Q surveillance is acceptable. The following paragraphs reiterate the more significant of the NRC staff conclusions.

Regarding changes to the TS associated with $F_Q^C(Z)$, or the instantaneous heat flux hot channel factor, the NRC staff determined that the new required actions and completion times are more restrictive than the existing, and as such, concluded that they are acceptable.

Regarding the reformulation of the $F_Q^W(Z)$ surveillance, the NRC staff developed the following review considerations:

1. The use of a planar radial surveillance in conjunction with T(Z) factors eliminates axial sensitivities in the surveillance procedure, and eliminates the current reliance on Westinghouse guidance to adjust W(Z) factors when performing $F_Q^W(Z)$ surveillance in conditions significantly different from those assumed in the RAOC or CAOC~~maneuvering~~ analysis. As noted in Section 4.1 of this SE, the surveillance formulation, i.e., treatment of uncertainties and power distribution perturbations over the surveillance interval, is otherwise equivalent to the existing.

2. ~~The PWROG proposed to introduce an additional factor to correct the surveillance parameter for conditions other than reference, i.e.,~~ The use of A_{XY} and A_Q~~,~~ to correct the surveillance parameter for conditions other than the reference condition, ~~and~~ as discussed in Sections 4.1 and 5.2 of this SE, ~~the NRC staff determined that the use of such parameters~~ was acceptable, provided the methodological description provided in response to RAI 15 is followed.

3. The incorporation of the R_j correction factor, which conservatively adjusts for downward trends in $F_Q^W(Z)$, directly into the surveillance supports the elimination of the NOTE associated with SR 3.2.1.2, as discussed in Sections 4.1 and 4.4 of this SE.

Based on the above considerations, the NRC staff concluded that the reformulated $F_Q^W(Z)$ surveillance was acceptable.

Finally, the NRC staff considered the revisions to the Required Actions associated with not meeting the $F_Q^W(Z)$ LCO, and determined that they are acceptable. The revision provides for successively more restrictive operating spaces, which help to ensure that the core operates with sufficient margin to ensure that the peak power remains within analyzed limits. Perhaps more importantly, the operating spaces and associated margin factors are now analytically based. This improvement provides assurance that completion of the Required Actions ($F_Q^W(Z)$ is not within its limits) would ensure that the core power distribution remains within the limits analyzed

in the ECCS evaluation. If the more restrictive operating spaces fail to provide the requisite margin, similar reductions in rated thermal power level and reactor trip setpoints to those required for $F_Q^C(Z)$ become necessary.

In conclusion, the NRC staff review determined that the revisions to the heat flux hot channel factor TS were acceptable. The revisions provide a more robust means for performing the $F_Q^W(Z)$ surveillance, a series of more restrictive operating spaces if the $F_Q^W(Z)$ LCO is not met, and a more clearly defined set of SRs and Required Actions. The TS changes also provide reasonable assurance that a core operated in accordance with these TS will remain within the power distribution limits assumed in the facility safety analyses.

5.0 APPROVAL LIMITATIONS

The NRC staff review identified three limitations, adherence to which are necessary to ensure acceptable implementation of WCAP-17661.

5.1 LIMITATION 1: ADHERENCE TO FUEL CONDITIONING GUIDELINES

As discussed in Sections 4.5 and 4.7 of this SE, PWROG justified the specification of certain surveillance intervals on the concept that rapid changes in power level are precluded by fuel conditioning guidelines, which require slower ascensions in power, and maintenance of periodic thermal power plateaus. However, the TS do not make adherence to these fuel conditioning guidelines an obligation. Even so, the staff acceptance of the PWROG justification was based on any given facility's adherence to these guidelines.

Thus, licensees implementing this TR (i.e., making the TS changes contained herein) must confirm, in the implementation request, that they adhere to Westinghouse fuel conditioning guidelines. Otherwise, implementing licensees must demonstrate to the NRC staff that similar requirements exist to provide assurance that the frequency of abrupt changes in power level is kept appropriately low during the initial power ascension of a fuel cycle. This TR is not applicable if continued adherence to such guidelines is not practiced.

Comment [a12]: See comment a10 above.

5.2 LIMITATION 2: USE OF A_{XY} AND A_Q

As discussed in Section 4.1.1 of this SE, the use of Methods 1 and 2 are acceptable for calculating A_{XY} and A_Q when performing RAOC and CAOC W(Z) surveillances, subject to the following limitations:

1. The NRC-approved methods provided in the response to RAI 15.b must be used to perform the surveillance-specific A_{XY} or A_Q calculations. Newer methods with similar capabilities may be considered acceptable provided the NRC staff specifically approves them for calculating A_{XY} and A_Q factors.

2. The depletion calculation used to determine the numerator and denominator of the A_{XY} or A_Q factor must be performed similarly to the original design calculation, as described in the response to RAI 15.c.

3. The use of Method 1 for calculating A_Q is only acceptable subject to the constraints discussed in the response to RAI 15.a. The surveillance Axial Offset must be within 1.5-percent of the target AO, and there must be assurance that the limiting $F_Q^W(Z)$ location does not lie within a rodded elevation at the time of surveillance.

Comment [a13]: See comment a9 above.

5.3 LIMITATION 3: POWER LEVEL REDUCTION TO 50 PERCENT RTP

As noted in Section 4.3.2 of this SE, the use of 50 percent as the final power level reduction in the event of failed F_Q surveillance is not included in the TS, but rather in the BASES and in the COLR. As such, this final power level, 50 percent, must be implemented on a plant-specific basis and included in COLR input generated using this methodology, in order to use this TR.

6.0 CONCLUSIONS

Based on the review described in the preceding SE, and subject to the limitations provided in Chapter 5, the NRC staff has determined that the RAOC and CAOC surveillance formulations and required actions proposed in WCAP-17661 are acceptable. The TR may be considered approved for use by the NRC staff, for the purpose of justifying the TS changes contained therein.

7.0 REFERENCES

1. PWROG, "Improved RAOC and CAOC F_Q Surveillance Requirements," Reports WCAP-17661-P (Proprietary) and WCAP-17661-NP (Publicly Available), and Transmittal Letter OG-13-427, Project No. 694, January 2, 2014, ADAMS Package Accession No. ML14009A098.

2. U.S. NRC, "Standard Technical Specifications – Westinghouse Plants," NUREG-1431, Volume 1, Revision 4, "Specifications," and Volume 2, Revision 4, "Bases," April 2012, ADAMS Accession Nos. ML12100A222 (Volume 1) and ML12100A228 (Volume 2).

3. PWROG, "Submittal of Request for Additional Information Response Regarding WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC RQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-16-273 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, September 13, 2016, ADAMS Package Accession No. ML16291A531.

4. PWROG, "Transmittal of the Response to Request for Additional Information, RAI 15 Associated with WCAP-17661-P/NP, Revision 1, Improved RAOC and CAOC FQ Surveillance Technical Specifications, PA-LSC-0795," Letter No. OG-18-35 and Enclosure 2 (Publicly Available) and Enclosure 1 (Proprietary), Project No. 694, February 15, 2018, ADAMS Package Accession No. ML18053A269.

5. Westinghouse Electric Company, "Relaxed Axial Offset Control F_Q Technical Specification Actions," NSAL-09-5, Revision 1, September 23, 2009. This document was not formally transmitted to the NRC and it is not available in ADAMS.

6. U.S. NRC, "Removal of Cycle-Specific Parameter Limits from Technical Specifications," Generic Letter 1988-16, October 4, 1988, ADAMS Accession No. ML031200485.

Attachment: Appendix

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APPENDIX: TABLES

TABLE 1: POWER DISTRIBUTION TERMS

1.A: Peaking Factors		
Term	Name	Definition
F_Q	Total Heat Flux Hot Channel Factor	The ratio of peak to average power density in the core
F_{XY}	Planar Radial Peaking Factor	The ratio of peak-to-average power density in a radial core plane

1.B: Limits, Functions, and Multipliers		
Term	Name	Definition
K(Z)	Axial shape function	Normalizes $F_Q(Z)$ as a function of core height. Included in COLR.
W(Z)	W(Z) function	Analytical ratios used in the current F_Q surveillance formulation to characterize the maximum expected increase in the surveillance *$F_Q(Z)$ x Power* relative to the non-equilibrium *$F_Q(Z)$ x Power.*
T(Z)	T(Z) function	Analytical ratios used in the improved F_Q surveillance formulation for RAOC plants to characterize the maximum transient P(Z)
CFQ	Rated thermal power (RTP) F_Q limit	Absolute limit applied to F_Q. Included in COLR. Term used in STS and STS Bases (Ref. 2).
P	Fraction of RTP	Used to scale the measured power distribution based on the core operating power level. Term used in STS and STS Bases (Ref. 2).
P_{rel}	Core average relative power	Same as fraction of RTP, above, but used in surveillance formulations presented in WCAP-17661.
P_{rel}^{SS}	Surveillance relative power	Actual power divided by the rated thermal power at the time of surveillance
P(Z)	Core average axial power shape	Planar average power at elevation Z, divided by volume average power of the core
$P(Z)_{ref}^{P}$	Relative axial power shape	Relative axial power predicted at the reference condition
PFXY	Power factor multiplier	Power factor multiplier for F_{XY}. Provided in the COLR.
A_{XY}	Correction factor for RAOC surveillance conditions	Used to adjust the $F_Q^W(Z)$ value in instances when the surveillance is conducted in a different condition, i.e., thermal power level and control rod insertion, than the reference condition (typically hot full power, all rods out, equilibrium xenon). ~~May be included in the COLR; c~~It can~~ould also~~ be calculated using a 3-D core simulator for specific surveillance conditions.
A_Q	Correction factor for CAOC surveillance conditions	Used to adjust the $F_Q^W(Z)$ value in instances when the surveillance is conducted in a different condition, i.e., thermal power level and control rod insertion, than the reference condition (typically hot full power, all rods out, equilibrium xenon). It can be calculated using a 3-D core simulator for specific surveillance conditions.
R_j	Penalty factor	Used to account for reductions in F_Q margin that may occur for trends that follow burnup over the surveillance interval

Comment [a14]: The text should be deleted, because Methods 3 and 4 were deleted from the Topical Report in the response to RAI 15.

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TABLE 1: POWER DISTRIBUTION TERMS (CONTINUED)

I.C: F_Q Terms		
Term	**Name**	**Definition**
$F_Q(Z)$	Heat flux hot channel factor	Maximum local heat flux on the surface of a fuel rod at core elevation Z, divided by the average fuel rod heat flux. In the WCAP-17661 methodology, this term is approximated by multiplying $F_{XY}(Z)$ by P(Z).
$F_Q^M(Z)$	Measured heat flux hot channel factor	Measured value of $F_Q(Z)$ obtained directly from the flux map results.
$F_Q^C(Z)$	--	The measured value, $F_Q^M(Z)$, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
$F_Q^W(Z)$	Transient $F_Q(Z)$	The maximum $F_Q(Z)$ calculated to occur in normal operation over the next surveillance interval. Includes margin for (1) fuel manufacturing tolerances, (2) flux map measurement uncertainty, and (3) operational transients anticipated over the next surveillance interval. The product of $F_Q^C(Z)$ and W(Z).
F_Q^{PR}	--	The predicted value of the Heat Flux Hot Channel Factor. A maximum value that includes load follow impacts.
F_Q^{RTP}	Rated thermal power F_Q limit	Same as CFQ.

I.D: F_{XY} Terms		
Term	**Name**	**Definition**
$F_{XY}(Z)$	Height-dependent radial peaking factor	Radial peaking factor, measured using the incore detector system, at a given plane of the core.
F_{XY}^M	--	The measured value of F_{XY} obtained directly from the flux map results.
F_{XY}^C	--	The measured value, F_{XY}^M, multiplied by a factor to account for fuel manufacturing tolerances and flux map measurement uncertainty.
F_{XY}^{RTP}	--	The limit of F_{XY} at RTP.
F_{XY}^L	--	The limit of F_{XY} at the current thermal power level.

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TABLE 2: SUMMARY OF PROPOSED CHANGES

2.A: Title			
TS Section and Requirements	Current Specifications	Revised Specifications	Justifications presented in the WCAP
TS 3.2.1B, Title	$F_Q(Z)$(RAOC-W(Z) Methodology)	$F_Q(Z)$(RAOC-T(Z) Methodology)	Use of a different methodology requires the name change

2.B: Actions, Condition A			
TS Section and Requirements	Current Specifications	Revised Specifications	Justifications presented in the WCAP
TS 3.2.1B and 3.2.1C, Required Actions A.2 and A.3	"… 1% for each 1% $F_Q^C(Z)$ exceeds limit"	"… 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action A.1."	Revised wording accounts for the possibility that the limit for $F_Q^C(Z)$ may be exceeded during a part-power surveillance. The current wording is only appropriate if the surveillance is performed at full power. The new wording will require greater setpoint reduction if the surveillance is performed at reduced power and $F_Q^C(z)$ exceeds its limit. (WCAP, Section 3.2.2, pg.3-12)
NOTE in Condition A	Required Action A.4 shall be completed whenever this Condition is entered.	Required Action A.4 shall be completed whenever this Condition is entered prior to increasing THERMAL POWER above the limit of Required Action A.1. SR 3.2.1.2 is not required to be performed if this Condition is entered prior to THERMAL POWER exceeding 75% RTP after a refueling.	Makes it consistent with other changes.

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1 TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.C: Actions, Condition B			
TS Section and Requirements	Current Specifications	Revised Specifications	Justifications presented in the WCAP
TS 3.2.1B and 3.2.1C, New Required Action B.1.1		B.1.1 states, "Implement a RAOC or CAOC operating space specified in the COLR that restores $F_Q^W(Z)$ to within limits."	Implementation of a New RAOC/CAOC operating space restores $F_Q^W(Z)$ within limits.
New Required Action B.1.2		B.1.2 states, "Perform SR 3.2.1.1 and SR 3.2.1.2 if control rod motion is required to comply with the new operating space."	When control rod motion is required, surveillance assures that $F_Q^W(Z)$ remains within limits.
TS 3.2.1B, Required Action B.2.1 (previously B.1)	Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER and reduce AFD limits as specified in the COLR.	Evaluations in the COLR will provide the applicable power level and AFD limits to assure $F_Q^W(Z)$ within limits.
TS 3.2.1C, Required Action B.2.1 (previously B.1)	Reduce THERMAL POWER ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limits	Limit THERMAL POWER to less than RATED THERMAL POWER as specified in the COLR.	Core models provide basis for determining the axial location of the minimum margin in the actual core.
TS 3.2.1B, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"… 1% for each 1% that the maximum allowable power of the AFD limits is reduced"	"… 1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	With the change, peak power densities will remain within limits of the safety analyses. Prior requirements may not ensure that non-equilibrium operation was bounded by the maximum power distribution assumptions in all circumstances.
TS 3.2.1C, Required Action B.2.2 and B.2.3 (previously B.2 and B.3)	"… 1% for each 1% $F_Q^W(Z)$ exceeds limits"	"…1% for each 1% that THERMAL POWER is limited below RATED THERMAL POWER by Required Action B.2.1."	
TS 3.2.1B, Completion Time for Required Action B.2.4	"Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits."	"Prior to increasing THERMAL POWER above the limit of Required Action B.2.1"	Proposed change in TS 3.2.1B will make it consistent with the Completion Time defined in TS 3.2.1C. Completion Time in TS 3.2.1C did not need any changes.
NOTE in Condition B	Applicable whenever Condition B is entered	Moved (with addition "prior to increasing THERMAL POWER above the limit of Required Action B.2.1") under Required Action B.2.1, i.e., applicable when Required Actions under B.2.1, B.2.2, B.2.3 and B.2.4 are entered.	Required Action option B.1 assumes that a RAOC operating space specified in the COLR satisfies $F_Q^C(Z)$ and $F_Q^W(Z)$ limits if no control rod (CR) motion is needed. Required Action B.1.2 requires surveillance CR motion is needed. Required Action B.2.4 institutes performance of the SRs if option B.2 is used.

TABLE 2: SUMMARY OF PROPOSED CHANGES (CONTINUED)

2.D: Surveillance Requirements (SRs)			
TS Section and Requirements	Current Specifications	Revised Specifications	Justifications presented in the WCAP
NOTE for SRs	NOTE states that "During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained."	The NOTE is deleted.	The NOTE has been a source of confusion and interpreted differently by various utilities. Existing frequencies, together, are unambiguous and appropriately verify $F_Q^C(Z)$ during the initial power escalation and throughout the operating cycle.
SR 3.2.1.1, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions …"	"Once within [24] hours after achieving equilibrium conditions …"	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.
NOTE for SR 3.2.1.2	The NOTE in SR 3.2.1.2 requiring increasing SR frequency considering an increase factor for $F_Q^W(Z)$ when increase from previous evaluation has been noted.	The NOTE is deleted.	The penalty factor in the improved methodology is based on predicted rather than measured trends in transient F_Q margin, and is applied when SR 3.2.1.2 is performed. It is argued that the past measurement trends are not indicative of future margin trends.
SR 3.2.1.2, 1st requirement in the Frequency column	"Once after each refueling prior to THERMAL POWER exceeding 75% RTP"	"Once after each refueling within [24] hours after achieving equilibrium conditions after THERMAL POWER exceeds 75% RTP."	Verification will still be performed within a reasonable time and prior to extended non-equilibrium operation at power levels where the maximum peak linear heat rate could potentially be challenged.
SR 3.2.1.2, 2nd requirement in the Frequency column	"Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THEMAL POWER at which $F_Q^W(Z)$ was last verified."	"Once within [24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THEMAL POWER at which $F_Q^W(Z)$ was last verified."	Frequency of 24 hours is contained in some plant TS and is a reasonable time period in which to perform this verification. Small likelihood of occurrence of undesirable condition within the time.

Comment [a15]: See comment a10 above.

Attachment 1- Comment a10 on the Revised

Draft Safety Evaluation for WCAP-17661

The initial Frequency for SR 3.2.1.2, will be revised as identified in the markup below. The Revised Draft Safety Evaluation for WCAP-17661 should be revised to eliminate reference to the Westinghouse Fuel Conditioning Guidelines or other equivalent Fuel Conditioning Guidelines.

Once after each refueling within [24] hours ~~after achieving equilibrium conditions~~ after thermal power exceeds 75% RTP

<u>AND</u>

Once within [24] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified

<u>AND</u>

[31 EFPD thereafter <u>OR</u> In accordance with the Surveillance Frequency Control Program]

The justification for this change is:

1) The change will address the primary concern in RAI #3 i.e.,:

   "It is not clear that the new Frequency will ensure that verification of $F_Q^W(Z)$ is performed prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged" and that there is the potential to operate for 31 EFPD without performing the first Surveillance of $F_Q^W(Z)$.

   By deleting the words "after achieving equilibrium conditions," a time limit is required for completing the first performance of SR 3.2.1.2 following a refueling once 75% RTP is reached. The revised Frequency establishes an unambiguous requirement to verify $F_Q^W(Z)$ before extended operation is permitted to occur at

relatively high power levels, while at the same time ensuring that the Surveillance will be performed at a power level high enough to provide a high level of confidence in the accuracy of the Surveillance result.

2) Although the core may not be in a complete equilibrium state for this first performance of the Surveillance after a refueling, the Surveillance will be performed under conditions where the core is sufficiently stable at the intended operating conditions required to perform the Surveillance. This, and the allowance to perform either a "Method 2" correction to the Surveillance using the $A_{XY}(Z)$ or $A_Q(Z)$ factors (as applicable), or alternatively to use Surveillance specific T(Z) or W(Z) Surveillance factors with no $A_{XY}(Z)$ or $A_Q(Z)$ correction factors, will ensure that the Surveillance result from the first performance of SR 3.2.1.2 after a refueling achieves the same overall level of accuracy as any other performance of SR 3.2.1.2.

3) If the first performance of SR 3.2.1.2 after a refueling is performed prior to thermal power exceeding 90% RTP, then the second Frequency will require an additional Surveillance to be performed within 24 hours after achieving equilibrium conditions after exceeding, by $\geq$ 10% RTP, the thermal power at which the first Surveillance was performed. However, even if that Surveillance is delayed, i.e., not performed due to a delay in reaching equilibrium conditions, compliance with the limit for $F_Q^W(Z)$ will already have been confirmed for the current operating space by the first performance of SR 3.2.1.2.

4) If the first performance of SR 3.2.1.2 after a refueling is performed after thermal power exceeds 90% RTP, then this initial Surveillance may not be repeated for another 31 EFPD. However, as stated in #2 above, the first performance of SR 3.2.1.2 at power levels greater than 75% will obtain the same overall level of accuracy as any other performance of SR 3.2.1.2, and is therefore sufficient to ensure compliance with the limit for $F_Q^W(Z)$ while operating in the current allowed operating space. .

5) The concern in RAI #8 is also addressed. This concern was with regard to the change to require verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding by ≥ 10% RTP, the THERMAL POWER at which the $F_Q^C(Z)$ or $F_Q^W(Z)$ was last verified. The primary justification made in the response to RAI #8 was that $F_Q^C(Z)$ and potentially $F_Q^W(Z)$, will already have been measured at least once at reduced power conditions, and that this provides assurance that increasing power up to the next power plateau will not result in exceeding the F_Q limit. It also provides assurance that the core is behaving as designed. By deleting the words "after achieving equilibrium conditions," from the first Frequency in SR 3.2.1.2, it provides certainty that $F_Q^W(Z)$ will have been measured at least once prior to the conditions required by the second Frequency for SR 3.2.1.2 becoming applicable. It will therefore no longer be necessary to rely on any limitations imposed on plant operations by the Westinghouse Fuel Conditioning Guidelines,

or other equivalent Fuel Conditioning Guidelines, to ensure compliance with the F_Q limit.

Note that additional changes will also be made to the TS Bases, associated with the above change to the first Frequency of SR 3.2.1.2.

Attachment 2

Revision to the Technical Specification (TS) Markups for

TS 3.2.1B and TS 3.2.1C

that were transmitted via OG-16-273

(Non-Proprietary)

(13 total pages including Attachment 2 cover page)

Technical Specification 3.2.1B
Heat Flux Hot Channel Factor Markups

3.2 POWER DISTRIBUTION LIMITS

3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-W(Z) Methodology)

LCO 3.2.1B $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered. ---------------------------------	A.1	Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	<u>AND</u>		
$F_Q^C(Z)$ not within limit.	A.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>		
	A.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>		
	A.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

ACTIONS (continued)

CONDITION	REQUIRED ACTION		COMPLETION TIME
B. ------------NOTE------------ Required Action B.4 shall be completed whenever this Condition is entered. -------------------------------	B.1	Reduce AFD limits ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit.	4 hours
$F_Q^W(Z)$ not within limits.	AND		
	B.2	Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced.	72 hours
	AND		
	B.3	Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% that the maximum allowable power of the AFD limits is reduced.	72 hours
	AND		
	B.4	Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the maximum allowable power of the AFD limits
C. Required Action and associated Completion Time not met.	C.1	Be in MODE 2.	6 hours

SURVEILLANCE REQUIREMENTS

-----NOTE-----
During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP <u>AND</u> Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified <u>AND</u> [31 EFPD thereafter <u>OR</u> In accordance with the Surveillance Frequency Control Program]

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	-------------------------------NOTE------------------------------- If measurements indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$: a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has not increased. --	
	Verify $F_Q^W(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP AND 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 AND

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter <u>OR</u> In accordance with the Surveillance Frequency Control Program]

Technical Specification 3.2.1C
Heat Flux Hot Channel Factor Markups

3.2 POWER DISTRIBUTION LIMITS

3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

LCO 3.2.1C $F_Q(Z)$, as approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$, shall be within the limits specified in the COLR.

APPLICABILITY: MODE 1.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. ------------NOTE------------ Required Action A.4 shall be completed whenever this Condition is entered. --------------------------------	A.1 Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^C(Z)$ exceeds limit.	15 minutes after each $F_Q^C(Z)$ determination
	<u>AND</u>	
$F_Q^C(Z)$ not within limit.	A.2 Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>	
	A.3 Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^C(Z)$ exceeds limit.	72 hours after each $F_Q^C(Z)$ determination
	<u>AND</u>	
	A.4 Perform SR 3.2.1.1 and SR 3.2.1.2.	Prior to increasing THERMAL POWER above the limit of Required Action A.1

ACTIONS (continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. ------------NOTE------------ Required Action B.4 shall be completed whenever this Condition is entered. -------------------------------- $F_Q^W(Z)$ not within limits.	B.1 Reduce THERMAL POWER ≥ 1% RTP for each 1% $F_Q^W(Z)$ exceeds limit. <u>AND</u> B.2 Reduce Power Range Neutron Flux - High trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit. <u>AND</u> B.3 Reduce Overpower ΔT trip setpoints ≥ 1% for each 1% $F_Q^W(Z)$ exceeds limit. <u>AND</u> B.4 Perform SR 3.2.1.1 and SR 3.2.1.2.	4 hours 72 hours 72 hours Prior to increasing THERMAL POWER above the limit of Required Action B.1
C. Required Action and associated Completion Time not met.	C.1 Be in MODE 2.	6 hours

SURVEILLANCE REQUIREMENTS

-----NOTE-----

During power escalation at the beginning of each cycle, THERMAL POWER may be increased until an equilibrium power level has been achieved, at which a power distribution map is obtained.

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify $F_Q^C(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP <u>AND</u> Once within [12] hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(Z)$ was last verified <u>AND</u> [31 EFPD thereafter <u>OR</u> In accordance with the Surveillance Frequency Control Program]

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE		FREQUENCY
SR 3.2.1.2	-------------------------------NOTE------------------------------ If measurements indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$: a. Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z [$F_Q^C(Z)$ / K(Z)] has not increased. ---	
	Verify $F_Q^W(Z)$ is within limit.	Once after each refueling prior to THERMAL POWER exceeding 75% RTP <u>AND</u> 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 <u>AND</u>

SURVEILLANCE REQUIREMENTS (continued)

SURVEILLANCE	FREQUENCY
	[31 EFPD thereafter OR In accordance with the Surveillance Frequency Control Program]

Attachment 3

Revision to the TS Bases Markups for

TS 3.2.1B and TS 3.2.1C

that were transmitted via OG-16-273 and OG-18-35

(Non-Proprietary)

(37 pages including Attachment 3 cover page)

Technical Specification Bases 3.2.1B
Heat Flux Hot Channel Factor Markups

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1B Heat Flux Hot Channel Factor ($F_Q(Z)$ (RAOC-W(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO(QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents an equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$F_Q(Z) \leq (CFQ / P)\ K(Z)$ for $P > 0.5$

$F_Q(Z) \leq (CFQ / 0.5)\ K(Z)$ for $P \leq 0.5$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized FQ(Z) as a function of core height provided in the COLR, and

P = THERMAL POWER / RTP

BASES

LCO (continued)

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of [2.32], and K(Z) is a function that looks like the one provided in Figure B 3.2.1B-1.

For Relaxed Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

The expression for $F_Q^W(Z)$ is:

$$F_Q^W(Z) = F_Q^C(Z)\,W(Z)$$

where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required and if $F_Q^W(Z)$ cannot be maintained within the LCO limits, reduction of the AFD limits is required. Note that sufficient reduction of the AFD limits will also result in a reduction of the core power.

Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.

Revised INSERT #1 for Bases B 3.2.1B

The various factors in this expression are defined below:

$F_{XY}^{M}(z)$ is the measured radial peaking factor at axial location z and is equal to the value of $F_Q^{M}(z)/P^{M}(z)$, where $P^{M}(z)$ is the measured core average axial power shape.

$[T(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[T(z)]^{COLR}$ functions are specified for each analyzed RAOC operating space (i.e., each unique combination of AFD limits and Control Bank Insertion Limits). The $[T(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each RAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[T(z)]^{COLR}$. The $[T(z)]^{COLR}$ functions also account for the following effects: (1) the presence of spacer grids in the fuel assembly, (2) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (3) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (4) the increase in radial peaking due to non-equilibrium xenon effects. The $[T(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at nominal RTP conditions with all shutdown and control rods fully withdrawn, i.e., all rods out (ARO). Surveillance specific $[T(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

$A_{XY}(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_{XY}^{M}(z)$ to the reference core conditions assumed in generating the $[T(z)]^{COLR}$ factors. Normally, this reference core condition is HFP, ARO, EQXE. For simplicity, $A_{XY}(z)$ may be assumed to be 1.0. If, however, margin is needed for a Surveillance performed at conditions different from the reference core conditions, then the appropriate values for $A_{XY}(z)$ may be used. Sub-factors of $A_{XY}(z)$ may also be determined and included in the COLR. These sub-factors are $F_{PC}(z)$ and $F_{RC}(z)$. $F_{PC}(z)$ is a factor that adjusts the measured $F_{XY}^{M}(z)$ to the reference core power (typically RTP) if the Surveillance is performed at part power conditions. $F_{RC}(z)$ is a factor that adjusts the measured $F_{XY}^{M}(z)$ values to the reference rodded condition (typically ARO) if the surveillance condition includes insertion of the lead control bank. When these sub-factors are used, $A_{XY}(z)$ is the product of $F_{PC}(z)$ and $F_{RC}(z)$.

[1.0815] is a factor that accounts for fuel manufacturing tolerances and measurement uncertainty.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^{W}(z)$ between Surveillances. Rj values are provided for each RAOC operating space.

--REVIEWER'S NOTE--
WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux - High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux - High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux - High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux - High trip setpoints.

BASES

ACTIONS (continued)

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by $\geq$ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1, ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

B.1

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. Reducing the AFD by $\geq$ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, restricts the axial flux distribution such that even if a transient occurred, core peaking factors are not exceeded.

BASES

ACTIONS (continued)

The implicit assumption is that if W(Z) values were recalculated (consistent with the reduced AFD limits), then $F_Q^C(Z)$ times the recalculated W(Z) values would meet the $F_Q(Z)$ limit. Note that complying with this action (of reducing AFD limits) may also result in a power reduction. Hence the need for Required Actions B.2, B.3 and B.4.

B.2

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% by which the maximum allowable power is reduced, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER as a result of reducing AFD limits in accordance with Required Action B.1.

B.3

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% by which the maximum allowable power is reduced, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER as a result of reducing AFD limits in accordance with Required Action B.1.

B.4

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the maximum allowable power limit imposed by Required Action B.1 ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

INSERT 2

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new RAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new RAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new RAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(Z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. It also requires reductions in the AFD limits by the amount specified in the COLR. If the RAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limit, then Required Action B.2.1 must be entered and THERMAL POWER must be limited to less than or equal to 50% RTP and AFD limits must be reduced by the amounts specified in the COLR. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

The Completion Time of 4 hours provides an acceptable time to reduce the THERMAL POWER and AFD limits in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(Z)$ and would require power reductions within 4 hours of the $F_Q^W(Z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(Z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

BASES

ACTIONS (continued)

C.1

If Required Actions A.1 through A.4 or B.1 through B.4 are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.

If THERMAL POWER has been increased by ≥ 10% RTP since the last determination of $F_Q^C(Z)$, another evaluation of this factor is required [12] hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

-----------------------------------REVIEWER'S NOTE-----------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called W(Z). Multiplying the measured total peaking factor, $F_Q^C(Z)$, by W(Z) gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

The W(Z) curve is provided in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for the following axial core regions, measured in percent of core height:

a. Lower core region, from 0 to 15% inclusive and

b. Upper core region, from 85 to 100% inclusive.

The top and bottom 15% of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.

If the two most recent $F_Q(Z)$ evaluations show an increase in the expression maximum over z [$F_Q^C(Z)$ / K(Z)], it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)

INSERT 3

The measured $F_Q(z)$ can be determined through a synthesis of the measured planar radial peaking factors, $F_{XY}^M(z)$, and the measured core average axial power shape, $P^M(z)$. Thus, $F_Q^C(z)$ is given by the following expression:

$$F_Q^C(z) = F_{XY}^M(z)\ P^M(z)\ [1.0815] = F_Q^M(z)\ [1.0815]$$

For RAOC operation, the analytical $[T(z)]^{COLR}$ functions, specified in the COLR for each RAOC operating space, are used together with the measured $F_{XY}(z)$ values to estimate $F_Q(z)$ for non-equilibrium operation within the RAOC operating space. When the $F_{XY}(z)$ values are measured at HFP ARO conditions ($A_{XY}(z)$ equals 1.0), $F_Q^W(z)$ is given by the following expression:

$$F_Q^W(z) = F_{XY}^M(z)\ [T(z)]^{COLR}\ Rj\ [1.0815]$$

Non-equilibrium operation can result in significant changes to the axial power shape. To a lesser extent, non-equilibrium operation can increase the radial peaking factors, $F_{XY}(z)$, through control rod insertion and through reduced Doppler and moderator feedback at part-power conditions.

The $[T(z)]^{COLR}$ functions quantify these effects for the range of power shapes, control rod insertion, and power levels characteristic of the operating space. Multiplying $[T(z)]^{COLR}$ by the measured full power, unrodded $F_{XY}^M(z)$ value, and the factor that accounts for manufacturing and measurement uncertainties gives $F_Q^W(z)$, the maximum total peaking factor postulated for non-equilibrium RAOC operation.

BASES

SURVEILLANCE REQUIREMENTS (continued)

---------------------------------REVIEWER'S NOTE---------------------------------
WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification," February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.
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or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.

Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.

$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.

[The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

---------------------------------REVIEWER'S NOTE---------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after achieving equilibrium conditions after exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. Also, initial startups following a refueling are slow and well controlled due to startup ramp rate limitations and fuel conditioning requirements. Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit. This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged by non-equilibrium operation.

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented.

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.

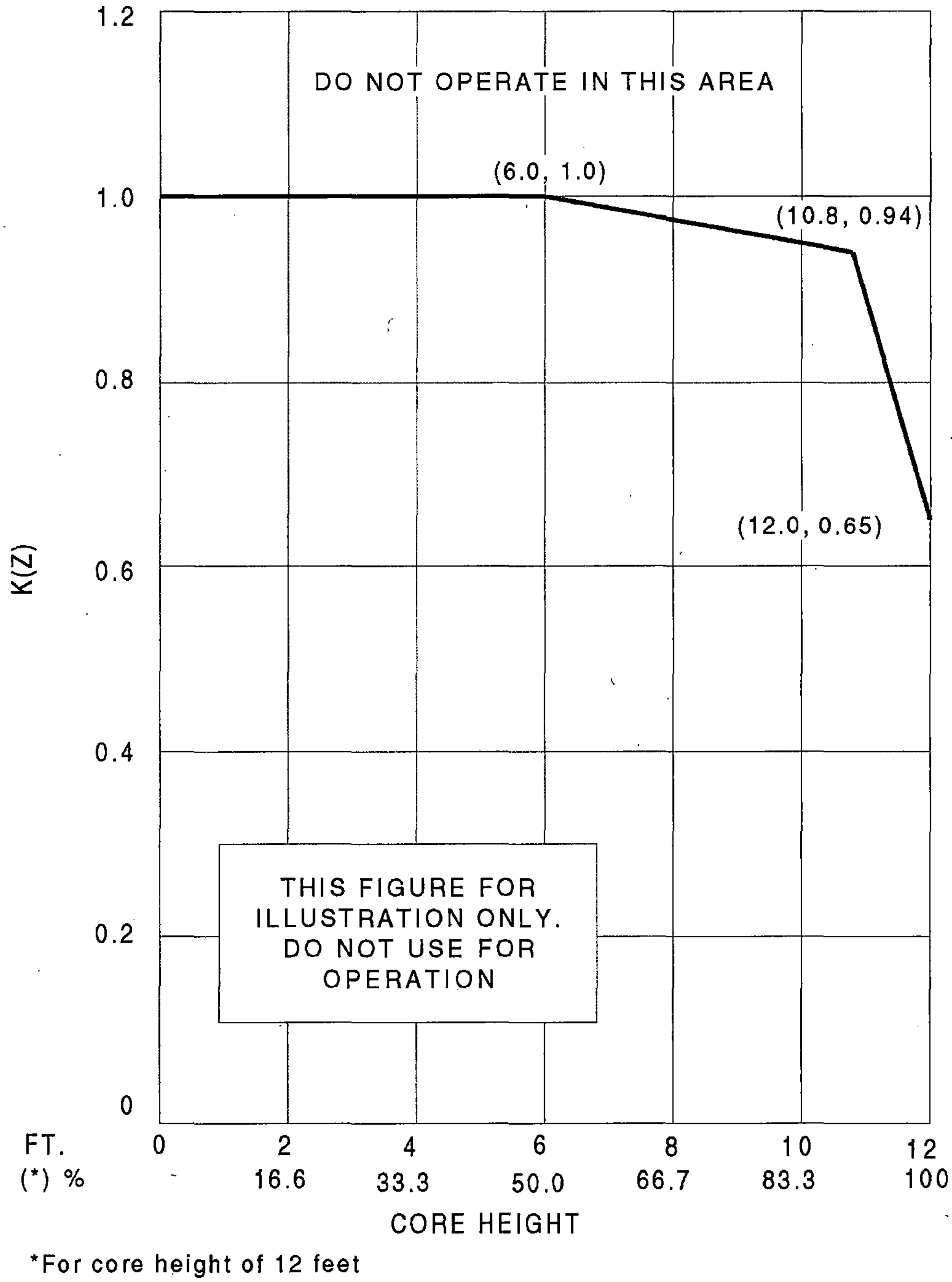
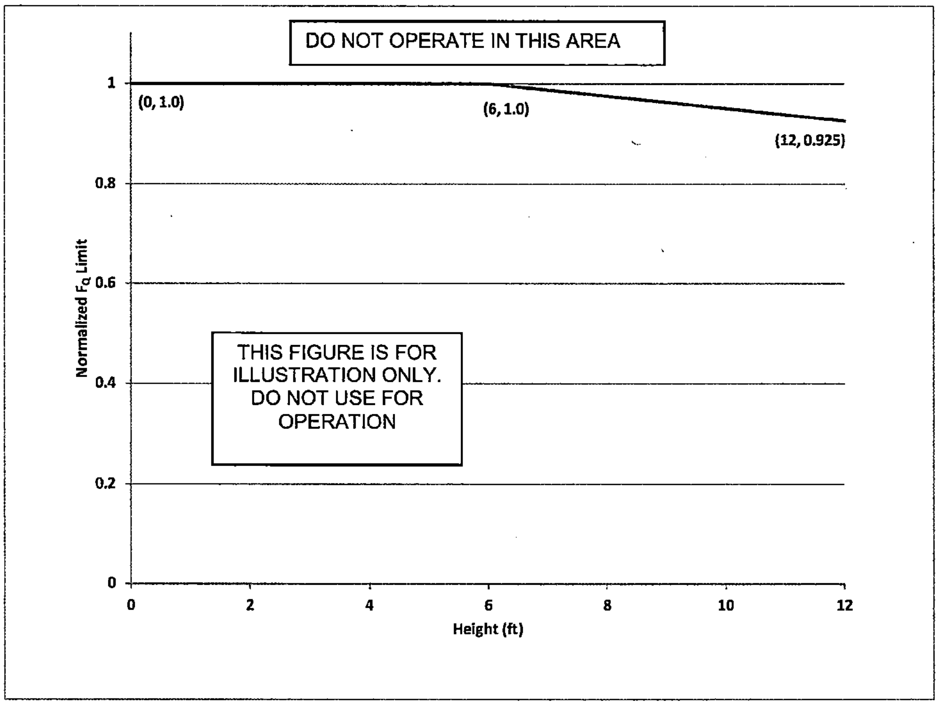


Figure B 3.2.1B-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
(0, 1.0)
(6, 1.0)
(12, 0.925)
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION
Normalized F_Q Limit
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Height (ft)

Technical Specification Bases 3.2.1C
Heat Flux Hot Channel Factor Markups

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1C Heat Flux Hot Channel Factor ($F_Q(Z)$ (CAOC-W(Z) Methodology)

BASES

BACKGROUND

The purpose of the limits on the values of $F_Q(Z)$ is to limit the local (i.e., pellet) peak power density. The value of $F_Q(Z)$ varies along the axial height (Z) of the core.

$F_Q(Z)$ is defined as the maximum local fuel rod linear power density divided by the average fuel rod linear power density, assuming nominal fuel pellet and fuel rod dimensions. Therefore, $F_Q(Z)$ is a measure of the peak fuel pellet power within the reactor core.

During power operation, the global power distribution is limited by LCO 3.2.3, "AXIAL FLUX DIFFERENCE (AFD)," and LCO 3.2.4, "QUADRANT POWER TILT RATIO (QPTR)," which are directly and continuously measured process variables. These LCOs, along with LCO 3.1.6, "Control Bank Insertion Limits," maintain the core limits on power distributions on a continuous basis.

$F_Q(Z)$ varies with fuel loading patterns, control bank insertion, fuel burnup, and changes in axial power distribution.

$F_Q(Z)$ is measured periodically using the incore detector system. These measurements are generally taken with the core at or near equilibrium conditions.

Using the measured three dimensional power distributions, it is possible to derive a measured value for $F_Q(Z)$. However, because this value represents a equilibrium condition, it does not include the variations in the value of $F_Q(Z)$ which are present during nonequilibrium situations such as load following or power ascension.

To account for these possible variations, the equilibrium value of $F_Q(Z)$ is adjusted as $F_Q^W(Z)$ by an elevation dependent factor that accounts for the calculated worst case transient conditions.

Core monitoring and control under non-equilibrium conditions are accomplished by operating the core within the limits of the appropriate LCOs, including the limits on AFD, QPTR, and control rod insertion.

BASES

APPLICABLE SAFETY ANALYSES

This LCO precludes core power distributions that violate the following fuel design criteria:

a. During a large break loss of coolant accident (LOCA), the peak cladding temperature must not exceed 2200°F (Ref. 1),

b. During a loss of forced reactor coolant flow accident, there must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hot fuel rod in the core does not experience a departure from nucleate boiling (DNB) condition,

c. During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm (Ref. 2), and

d. The control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod stuck fully withdrawn (Ref. 3).

Limits on $F_Q(Z)$ ensure that the value of the initial total peaking factor assumed in the accident analyses remains valid. Other criteria must also be met (e.g., maximum cladding oxidation, maximum hydrogen generation, coolable geometry, and long term cooling). However, the peak cladding temperature is typically most limiting.

$F_Q(Z)$ limits assumed in the LOCA analysis are typically limiting relative to (i.e., lower than) the $F_Q(Z)$ limit assumed in safety analyses for other postulated accidents. Therefore, this LCO provides conservative limits for other postulated accidents.

$F_Q(Z)$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The Heat Flux Hot Channel Factor, $F_Q(Z)$, shall be limited by the following relationships:

$$F_Q(Z) \leq (\ CFQ/P\ )\ K(Z) \qquad \text{for } P > 0.5$$

$$F_Q(Z) \leq (\ CFQ/0.5\ )\ K(Z) \qquad \text{for } P \leq 0.5$$

where: CFQ is the $F_Q(Z)$ limit at RTP provided in the COLR,

K(Z) is the normalized $F_Q(Z)$ as a function of core height provided in the COLR, and

P = THERMAL POWER/RTP

BASES

LCO (continued)

For this facility, the actual values of CFQ and K(Z) are given in the COLR; however, CFQ is normally a number on the order of [2.32], and K(Z) is a function that looks like the one provided in Figure B 3.2.1C-1.

For Constant Axial Offset Control operation, $F_Q(Z)$ is approximated by $F_Q^C(Z)$ and $F_Q^W(Z)$. Thus, both $F_Q^C(Z)$ and $F_Q^W(Z)$ must meet the preceding limits on $F_Q(Z)$.

An $F_Q^C(Z)$ evaluation requires obtaining an incore flux map in MODE 1. From the incore flux map results we obtain the measured value ($F_Q^M(Z)$) of $F_Q(Z)$. Then,

$$F_Q^C(Z) = F_Q^M(Z)\ [1.0815]$$

where [1.0815] is a factor that accounts for fuel manufacturing tolerances and flux map measurement uncertainty.

$F_Q^C(Z)$ is an excellent approximation for $F_Q(Z)$ when the reactor is at the steady state power at which the incore flux map was taken.

The expression for $F_Q^W(Z)$ is:

$$F_Q^W(Z) = F_Q^C(Z)\ W(Z)$$

where W(Z) is a cycle dependent function that accounts for power distribution transients encountered during normal operation. W(Z) is included in the COLR. The $F_Q^C(Z)$ is calculated at equilibrium conditions.

The $F_Q(Z)$ limits define limiting values for core power peaking that precludes peak cladding temperatures above 2200°F during either a large or small break LOCA.

This LCO requires operation within the bounds assumed in the safety analyses. Calculations are performed in the core design process to confirm that the core can be controlled in such a manner during operation that it can stay within the LOCA $F_Q(Z)$ limits. If $F_Q^C(Z)$ cannot be maintained within the LCO limits, reduction of the core power is required.

Violating the LCO limits for $F_Q(Z)$ produces unacceptable consequences if a design basis event occurs while $F_Q(Z)$ is outside its specified limits.

Revised INSERT #1 for Bases B 3.2.1C

$[W(z)]^{COLR}$ is the cycle and burnup dependent function, specified in the COLR, which accounts for power distribution transients encountered during non-equilibrium normal operation. $[W(z)]^{COLR}$ functions are specified for each analyzed CAOC operating space (i.e., each unique combination of AFD band and Control Bank Insertion Limits). The $[W(z)]^{COLR}$ functions account for the limiting non-equilibrium axial power shapes postulated to occur during normal operation for each CAOC operating space. Limiting power shapes at both full and reduced power operation are considered in determining the maximum values of $[W(z)]^{COLR}$. The $[W(z)]^{COLR}$ functions also account for the following effects: (1) the increase in radial peaking in rodded core planes due to the presence of control rods during non-equilibrium normal operation, (2) the increase in radial peaking that occurs during part-power operation due to reduced fuel and moderator temperatures, and (3) the increase in radial peaking due to non-equilibrium xenon effects. The $[W(z)]^{COLR}$ functions are normally calculated assuming that the Surveillance is performed at the Target Axial Offset core conditions. Surveillance specific $[W(z)]^{COLR}$ values may be generated for a given surveillance core condition.

P is the THERMAL POWER / RTP.

$A_Q(z)$ is a cycle, burnup, and power dependent function specified in the COLR or determined at the time of the surveillance using an approved 3D core model and the methodology of Reference 6. It adjusts the measured $F_Q^M(z)$ to the Target Axial Offset core conditions. For simplicity, $A_Q(z)$ may be assumed to be 1.0 when the surveillance is performed at the target AO. If, however, margin is needed for a Surveillance performed at conditions different from the Target AO core conditions, then the appropriate values for $A_Q(z)$ may be used.

Rj is a cycle and burnup dependent analytical factor specified in the COLR that accounts for potential increases in $F_Q^W(z)$ between Surveillances. Rj values are provided for each CAOC operating space.

-----------------------------------REVIEWER'S NOTE-----------------------------------

WCAP-17661-P-A, "Improved RAOC and CAOC F_Q Surveillance Technical Specifications," or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.

BASES

APPLICABILITY

The $F_Q(Z)$ limits must be maintained in MODE 1 to prevent core power distributions from exceeding the limits assumed in the safety analyses. Applicability in other MODES is not required because there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to require a limit on the distribution of core power.

ACTIONS

A.1

Reducing THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^C(Z)$ exceeds its limit, maintains an acceptable absolute power density. $F_Q^C(Z)$ is $F_Q^M(Z)$ multiplied by a factor accounting for manufacturing tolerances and measurement uncertainties. $F_Q^M(Z)$ is the measured value of $F_Q(Z)$. The Completion Time of 15 minutes provides an acceptable time to reduce power in an orderly manner and without allowing the plant to remain in an unacceptable condition for an extended period of time. The maximum allowable power level initially determined by Required Action A.1 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require power reductions within 15 minutes of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable power level. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable power level and increasing power up to this revised limit.

A.2

A reduction of the Power Range Neutron Flux - High trip setpoints by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Power Range Neutron Flux – High trip setpoints initially determined by Required Action A.2 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Power Range Neutron Flux – High trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Power Range Neutron Flux – High trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum allowable Power Range Neutron Flux – High trip setpoints.

BASES

ACTIONS (continued)

A.3

Reduction in the Overpower ΔT trip setpoints (value of K_4) by ≥ 1% for each 1% by which $F_Q^C(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action A.1. The maximum allowable Overpower ΔT trip setpoints initially determined by Required Action A.3 may be affected by subsequent determinations of $F_Q^C(Z)$ and would require Overpower ΔT trip setpoint reductions within 72 hours of the $F_Q^C(Z)$ determination, if necessary to comply with the decreased maximum allowable Overpower ΔT trip setpoints. Decreases in $F_Q^C(Z)$ would allow increasing the maximum Overpower ΔT trip setpoints.

A.4

Verification that $F_Q^C(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action A.1, ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition A is modified by a Note that requires Required Action A.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action A.1, even when Condition A is exited prior to performing Required Action A.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

B.1

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational

BASES

ACTIONS (continued)

transient occurs. Reducing the THERMAL POWER by ≥ 1% RTP for each 1% by which $F_Q^W(Z)$ exceeds its limit within the allowed Completion Time of 4 hours, maintains an acceptable absolute power density such that even if a transient occurred, core peaking factors are not exceeded.

B.2

A reduction of the Power Range Neutron Flux-High trip setpoints by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period and the preceding prompt reduction in THERMAL POWER in accordance with Required Action B.1.

B.3

Reduction in the Overpower ΔT trip setpoints value of K_4 by ≥ 1% for each 1% by which $F_Q^W(Z)$ exceeds its limit, is a conservative action for protection against the consequences of severe transients with unanalyzed power distributions. The Completion Time of 72 hours is sufficient considering the small likelihood of a severe transient in this time period, and the preceding prompt reduction in THERMAL POWER in accordance with Required Action B.1.

B.4

Verification that $F_Q^W(Z)$ has been restored to within its limit, by performing SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit imposed by Required Action B.1 ensures that core conditions during operation at higher power levels and future operation are consistent with safety analyses assumptions.

Condition B is modified by a Note that requires Required Action B.4 to be performed whenever the Condition is entered. This ensures that SR 3.2.1.1 and SR 3.2.1.2 will be performed prior to increasing THERMAL POWER above the limit of Required Action B.1, even when Condition A is exited prior to performing Required Action B.4. Performance of SR 3.2.1.1 and SR 3.2.1.2 are necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

INSERT 2

Implementing a more restrictive CAOC operating space, specified in the COLR, within the allowed Completion Time of 4 hours will restrict the AFD such that core peaking factor limits will not be exceeded during non-equilibrium normal operation. Several CAOC operating spaces, representing successively smaller AFD bands and, optionally, shallower Control Bank Insertion Limits, may be specified in the COLR. The corresponding $[W(z)]^{COLR}$ functions for these operating spaces can be used to determine which CAOC operating space would result in acceptable non-equilibrium operation within the $FQ^{W}(z)$ limit.

INSERT 3

B.1.2

If it is found that the maximum calculated value of $F_Q(Z)$ that can occur during normal maneuvers, $F_Q^W(Z)$, exceeds its specified limits, there exists a potential for $F_Q^C(Z)$ to become excessively high if a normal operational transient occurs. As discussed above, Required Action B.1.1 requires that a new CAOC operating space be implemented to restore $F_Q^W(Z)$ to within its limits. Required Action B.1.2 requires that SR 3.2.1.1 and SR 3.2.1.2 be performed if control rod motion occurs as a result of implementing the new CAOC operating space in accordance with Required Action B.1.1. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated after any rod motion resulting from the implementation of a new CAOC operating space in accordance with Required Action B.1.1.

B.2.1

When $F_Q^W(z)$ exceeds its limit, Required Action B.2.1 may be implemented instead of Required Action B.1. Required Action B.2.1 limits THERMAL POWER to less than RATED THERMAL POWER by the amount specified in the COLR. If the more restrictive CAOC operating spaces specified in the COLR are insufficient to ensure margin to the $F_Q^W(z)$ limit, the THERMAL POWER must be limited to less than or equal to 50% RTP. This maintains an acceptable absolute power density relative to the maximum power density value assumed in the safety analyses.

If the required $F_Q^W(z)$ margin improvement exceeds the margin improvement available from the pre-analyzed THERMAL POWER and AFD reductions provided in the COLR, then THERMAL POWER must be further reduced to less than or equal to 50% RTP. In this case, reducing THERMAL POWER to less than or equal to 50% RTP will provide additional margin in the transient F_Q by the required change in THERMAL POWER and the increase in the F_Q limit. This will ensure that the F_Q limit is met during transient operation that may occur at or below 50% RTP.

INSERT 3 (continued)

The Completion Time of 4 hours provides an acceptable time to reduce power in an orderly manner to preclude entering an unacceptable condition during future non-equilibrium operation. The limit on THERMAL POWER initially determined by Required Action B.2.1 may be affected by subsequent determinations of $F_Q^W(z)$ and would require power reductions within 4 hours of the $F_Q^W(z)$ determination, if necessary to comply with the decreased THERMAL POWER limit. Decreases in $F_Q^W(z)$ would allow increasing the THERMAL POWER limit and increasing THERMAL POWER up to this revised limit.

Required Action B.2.1 is modified by a Note that states Required Action B.2.4 shall be completed whenever Required Action B.2.1 is performed prior to increasing THERMAL POWER above the limit of Required Action B.2.1. Required Action B.2.4 requires the performance of SR 3.2.1.1 and SR 3.2.1.2 prior to increasing THERMAL POWER above the limit established by Required Action B.2.1. The Note ensures that the SRs will be performed even if Condition B may be exited prior to performing Required Action B.2.4. The performance of SR 3.2.1.1 and SR 3.2.1.2 is necessary to assure $F_Q(Z)$ is properly evaluated prior to increasing THERMAL POWER.

If an F_Q surveillance is performed at 100% RTP conditions, and both $F_Q^C(Z)$ and $F_Q^W(Z)$ exceed their limits, the option to reduce the THERMAL POWER limit in accordance with proposed Required Action B.2.1 instead of implementing a new operating space in accordance with proposed Required Action B.1, will result in a further power reduction after Required Action A.1 has been completed. However, this further power reduction would be permitted to occur over the next 4 hours. In the event the evaluated THERMAL POWER reduction in the COLR for proposed Required Action B.2.1 did not result in a further power reduction (for example, if both Condition A and Condition B were entered at less than 100% RTP conditions), then the THERMAL POWER level established as a result of completing Required Action A.1 will take precedence, and will establish the effective operating power level limit for the unit until both Conditions A and B are exited.

BASES

ACTIONS (continued)

C.1

If Required Actions A.1 through A.4 or B.1 through B.4 are not met within their associated Completion Times, the plant must be placed in a mode or condition in which the LCO requirements are not applicable. This is done by placing the plant in at least MODE 2 within 6 hours.

This allowed Completion Time is reasonable based on operating experience regarding the amount of time it takes to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1 and SR 3.2.1.2 are modified by a Note. The Note applies during the first power ascension after a refueling. It states that THERMAL POWER may be increased until an equilibrium power level has been achieved at which a power distribution map can be obtained. This allowance is modified, however, by one of the Frequency conditions that requires verification that $F_Q^C(Z)$ and $F_Q^W(Z)$ are within their specified limits after a power rise of more than 10% RTP over the THERMAL POWER at which they were last verified to be within specified limits. Because $F_Q^C(Z)$ and $F_Q^W(Z)$ could not have previously been measured in this reload core, there is a second Frequency condition, applicable only for reload cores, that requires determination of these parameters before exceeding 75% RTP. This 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. Also, this Frequency condition, together with the Frequency condition requiring verification of $F_Q^C(Z)$ and $F_Q^W(Z)$ following a power increase of more than 10%, ensures that they are verified as soon as RTP (or any other level for extended operation) is achieved. In the absence of these Frequency conditions, it is possible to increase power to RTP and operate for 31 days without verification of $F_Q^C(Z)$ and $F_Q^W(Z)$. The Frequency condition is not intended to require verification of these parameters after every 10% increase in power level above the last verification. It only requires verification after a power level is achieved for extended operation that is 10% higher than that power at which $F_Q(Z)$ was last measured.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.1

Verification that $F_Q^C(Z)$ is within its specified limits involves increasing $F_Q^M(Z)$ to allow for manufacturing tolerance and measurement uncertainties in order to obtain $F_Q^C(Z)$. Specifically, $F_Q^M(Z)$ is the measured value of $F_Q(Z)$ obtained from incore flux map results and $F_Q^C(Z) = F_Q^M(Z)$ [1.0815] (Ref. 4). $F_Q^C(Z)$ is then compared to its specified limits.

The limit with which $F_Q^C(Z)$ is compared varies inversely with power above 50% RTP and directly with a function called K(Z) provided in the COLR.

Performing this Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q^C(Z)$ limit is met when RTP is achieved, because peaking factors generally decrease as power level is increased.

If THERMAL POWER has been increased by ≥ 10% RTP since the last determination of $F_Q^C(Z)$, another evaluation of this factor is required [12] hours after achieving equilibrium conditions at this higher power level (to ensure that $F_Q^C(Z)$ values are being reduced sufficiently with power increase to stay within the LCO limits).

[The Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup because such changes are slow and well controlled when the plant is operated in accordance with the Technical Specifications (TS).

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

----------------------------------REVIEWER'S NOTE----------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
--]

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.1.2

The nuclear design process includes calculations performed to determine that the core can be operated within the $F_Q(Z)$ limits. Because flux maps are taken in steady state conditions, the variations in power distribution resulting from normal operational maneuvers are not present in the flux map data. These variations are, however, conservatively calculated by considering a wide range of unit maneuvers in normal operation. The maximum peaking factor increase over steady state values, calculated as a function of core elevation, Z, is called W(Z). Multiplying the measured total peaking factor, $F_Q^C(Z)$, by W(Z) gives the maximum $F_Q(Z)$ calculated to occur in normal operation, $F_Q^W(Z)$.

The limit with which $F_Q^W(Z)$ is compared varies inversely with power above 50% RTP and directly with the function K(Z) provided in the COLR.

The W(Z) curve is provided in the COLR for discrete core elevations. Flux map data are typically taken for 30 to 75 core elevations. $F_Q^W(Z)$ evaluations are not applicable for the following axial core regions, measured in percent of core height:

a. Lower core region, from 0 to 15% inclusive and

b. Upper core region, from 85 to 100% inclusive.

The top and bottom 15% of the core are excluded from the evaluation because of the low probability that these regions would be more limiting in the safety analyses and because of the difficulty of making a precise measurement in these regions.

This Surveillance has been modified by a Note that may require that more frequent surveillances be performed. If $F_Q^W(Z)$ is evaluated, an evaluation of the expression below is required to account for any increase to $F_Q^M(Z)$ that may occur and cause the $F_Q(Z)$ limit to be exceeded before the next required $F_Q(Z)$ evaluation.

If the two most recent $F_Q(Z)$ evaluations show an increase in the expression

maximum over z $[F_Q^C(Z) / K(Z)]$,

it is required to meet the $F_Q(Z)$ limit with the last $F_Q^W(Z)$ increased by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR (Ref. 5)

BASES

SURVEILLANCE REQUIREMENTS (continued)

----------------------------------REVIEWER'S NOTE----------------------------------
WCAP-10216-P-A, Rev. 1A, Relaxation of Constant Axial Offset Control and F_Q Surveillance Technical Specification, February 1994, or other appropriate plant specific methodology, is to be listed in the COLR description in the Administrative Controls Section 5.0 to address the methodology used to derive this factor.
----

or to evaluate $F_Q(Z)$ more frequently, each 7 EFPD. These alternative requirements prevent $F_Q(Z)$ from exceeding its limit for any significant period of time without detection.

Performing the Surveillance in MODE 1 prior to exceeding 75% RTP ensures that the $F_Q(Z)$ limit is met when RTP is achieved, because peaking factors are generally decreased as power level is increased.

$F_Q(Z)$ is verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification, [12] hours after achieving equilibrium conditions to ensure that $F_Q(Z)$ is within its limit at higher power levels.

[The Surveillance Frequency of 31 EFPD is adequate to monitor the change of power distribution with core burnup. The Surveillance may be done more frequently if required by the results of $F_Q(Z)$ evaluations.

The Frequency of 31 EFPD is adequate to monitor the change of power distribution because such a change is sufficiently slow, when the plant is operated in accordance with the TS, to preclude adverse peaking factors between 31 day surveillances.

OR

The Surveillance Frequency is controlled under the Surveillance Frequency Control Program.

----------------------------------REVIEWER'S NOTE----------------------------------
Plants controlling Surveillance Frequencies under a Surveillance Frequency Control Program should utilize the appropriate Frequency description, given above, and the appropriate choice of Frequency in the Surveillance Requirement.
---]

INSERT 4

SR 3.2.1.2 requires a Surveillance of $F_Q^W(z)$ during the initial startup following each refueling within [24] hours after achieving equilibrium conditions after exceeding 75% RTP. THERMAL POWER levels below 75% are typically non-limiting with respect to the limit for $F_Q^W(z)$. Also, initial startups following a refueling are slow and well controlled due to startup ramp rate limitations and fuel conditioning requirements. Furthermore, startup physics testing and flux symmetry measurements, also performed at low power, provide confirmation that the core is operating as expected. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit. This Frequency ensures that verification of $F_Q^W(z)$ is performed prior to extended operation at power levels where the maximum permitted peak LHR could be challenged by non-equilibrium operation.

Equilibrium conditions are achieved when the core is sufficiently stable at the intended operating conditions required to perform the Surveillance.

If a previous Surveillance of $F_Q^W(z)$ was performed at part power conditions, SR 3.2.1.2 also requires that $F_Q^W(z)$ be verified at power levels ≥ 10% RTP above the THERMAL POWER of its last verification within [24] hours after achieving equilibrium conditions. This ensures that $F_Q^W(z)$ is within its limit using radial peaking factors measured at the higher power level.

The allowance of up to 24 hours after achieving equilibrium conditions will provide a more accurate measurement of $F_Q^W(Z)$ by allowing sufficient time to achieve equilibrium conditions and obtain the power distribution measurement while still requiring performance of the surveillance before the fuel becomes sufficiently conditioned such that load follow operation can be implemented.

BASES

REFERENCES

1. 10 CFR 50.46, 1974.
2. Regulatory Guide 1.77, Rev. 0, May 1974.
3. 10 CFR 50, Appendix A, GDC 26.
4. WCAP-7308-L-P-A, "Evaluation of Nuclear Hot Channel Factor Uncertainties," June 1988.
5. WCAP-10216-P-A, Rev. 1A, "Relaxation of Constant Axial Offset Control (and) F_Q Surveillance Technical Specification," February 1994.

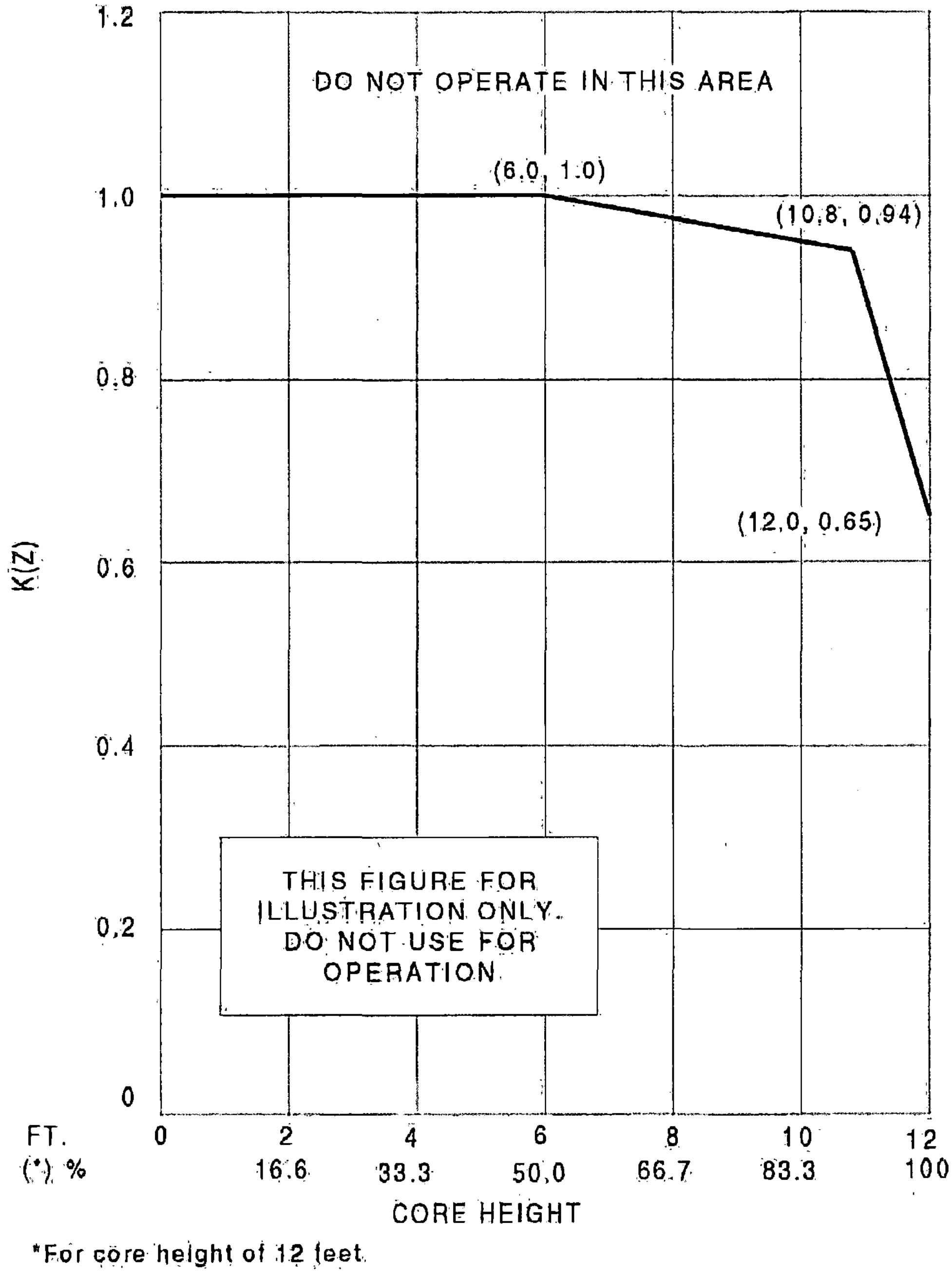
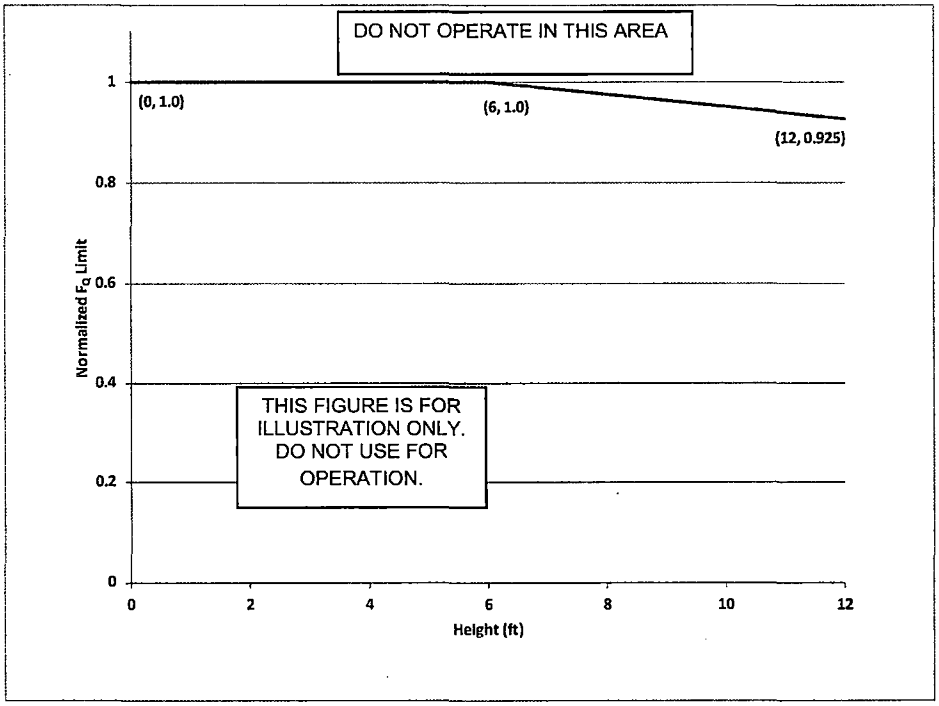


Figure B 3.2.1C-1 (page 1 of 1)
K(Z) - Normalized $F_Q(Z)$ as a Function of Core Height


DO NOT OPERATE IN THIS AREA
(0, 1.0)
(6, 1.0)
(12, 0.925)
Normalized Fq Limit
Height (ft)
THIS FIGURE IS FOR ILLUSTRATION ONLY. DO NOT USE FOR OPERATION.

ATTACHMENT 4

WCAP-17661-P/ WCAP-17661-NP, Revision 1

Markup Pages (PA-LSC-0795)

(8 pages including Attachment 4 cover page)

In addition to these difficulties with the F_Q Surveillance formulation, there is an important shortcoming with the RAOC F_Q Surveillance (TS) itself. Required Action B.1 in the RAOC TS 3.2.1B (Reference 1) requires a reduction in the AFD envelope by $\geq 1\%$ for each 1% that $F_Q(z)$ exceeds its limit. This Required Action, however, does not adequately restore F_Q margin in all circumstances. [

]^{a,c}

To briefly summarize, there are two primary issues with the current RAOC F_Q Surveillance formulation and TS 3.2.1B (Reference 1):

1. Sensitivity of the formulation to the differences between the measured and predicted surveillance power shapes at both nominal and part power conditions

2. Potential non-conservatisms in the AFD reduction required action

In the improved RAOC F_Q Surveillance formulation and TS, these issues are addressed as follows:

Instead of the requiring measurement of the $F_Q(z)$ for RAOC plants, the improved formulation will require measurement of $F_{XY}(z)$. These measured peaking factors are then multiplied by factors that characterize the maximum transient P(z) values postulated to occur during non-equilibrium operation. P(z) is the core average axial power shape. This formulation essentially eliminates the sensitivity of the surveillance to the surveillance axial power shape, but retains the essential feature of incorporating the measured radial peaking factors into the surveillance $F_Q(z)$ values.

This new formulation will also improve the accuracy of part-power surveillances. The improved F_Q Technical Specification, however, also revises the Frequencies of the TS by requiring that the first F_Q Surveillance following a refueling must be performed after ~~achieving equilibrium conditions at a power greater than~~ exceeding 75% of RTP.

Finally, the improved RAOC F_Q Surveillance TS incorporates the concept of RAOC operating spaces. A RAOC operating space (ROS) is a unique combination of Control Bank Insertion Limits and AFD limits. In the improved F_Q TS, transient surveillance factors are pre-calculated for multiple RAOC operating space assumptions. The RAOC operating spaces are specified in the Core Operating Limits Report (COLR). If the F_Q limit is exceeded during a surveillance, a more restrictive RAOC operating space is implemented that provides the required additional F_Q margin for future operation. In the unlikely event that no RAOC operating space provides the required margin improvement, then thermal power limits and AFD reductions specified in the COLR must be implemented.

While the current F_Q Surveillance formulation works well for CAOC plants, a minor revision is made to this formulation to permit adjustment of the surveillance to the target axial offset (AO) core conditions. Also, the improved CAOC F_Q Surveillance TS incorporates the concept of operating spaces. The current CAOC F_Q Surveillance TS requires a power level reduction if the F_Q limit is exceeded. The improved F_Q TS provides the option of implementing a more restrictive CAOC operating space, which is defined as a unique combination of AFD band and Control Bank Insertion Limits. The CAOC operating spaces are specified in the COLR. The appendices provide the new RAOC and CAOC F_Q Surveillance Technical Specifications and Bases as well as sample COLRs.

resulting from non-equilibrium operation. In the new formulation, the radial $F_{XY}(z)$ peaking factors are measured and multiplied by the T(z) factors to obtain the "measured" $F_Q^W(z)$, which is the transient $F_Q(z)$. The measured steady-state axial power shape is not used in the surveillance, nor is the predicted surveillance axial power shape. This new formulation will also improve the accuracy of part-power surveillances since the surveillance axial power shape is not used to determine the measured transient $F_Q(z)$. Use of the surveillance axial power shape in the part-power transient $F_Q(z)$ measurement is a major source of the "over-measurement" that can lead to anomalous reductions in transient F_Q margin for part-power surveillances.

To address the non-conservatism in Required Action B.1, the improved RAOC F_Q Technical Specification is structured to permit multiple RAOC operating spaces to be defined in the COLR. The COLR will include T(z) functions for each RAOC operating space, which is defined as a unique combination of AFD limits and control bank insertion limits. If the plant measures a transient F_Q violation, then a more restrictive RAOC operating space can be selected from the COLR that provides the required margin for future non-equilibrium operation. This retains the feature of using an AFD reduction to gain margin, but in a manner that ensures that appropriate margin is recovered. If none of the RAOC operating spaces included in the COLR provides the required margin, then limits on thermal power and AFD must be implemented. These limits are specified in the COLR. The analysis methods used to determine the T(z) values are described in this report as are the methods used to determine the limits on thermal power and AFD.

The new RAOC F_Q Surveillance Technical Specification also improves and clarifies the Surveillance Requirements. Following a refueling, the improved F_Q Technical Specification requires a surveillance of the current $F_Q(z)$, $F_Q^C(z)$, prior to exceeding 75% RTP. The first surveillance of $F_Q^W(z)$, however, is not required until equilibrium conditions are established after 75% RTP is exceeded. The current F_Q TS specifies that the first surveillance of $F_Q^W(z)$ should occur prior to exceeding 75% RTP. Also, the rigor of accounting for transient peaking factor increases between surveillances is improved in the new Technical Specification by tying the application of the penalty factor that accounts for the peaking factor increase between surveillances directly to predicted $F_Q^W(z)$ margin reductions for operation during the next surveillance interval (31 EFPD). The current F_Q specification requires application of the penalty factor only if $F_Q^C(z)/K(z)$ has increased over the <u>previous</u> surveillance interval, where K(z) is the axial shape function for the $F_Q(z)$ limit. Consequently, the improved F_Q TS will better account for the expected future margin trend.

The new version of the CAOC F_Q Surveillance Technical Specification improves the specification by providing an alternative to a power reduction when the transient F_Q limit is exceeded. The current Required Action B.1 of Technical Specification 3.2.1C (Reference 1) requires a $\geq$ 1% power reduction for each 1% that $F_Q^W(z)$ exceeds its limit. In the new version of the CAOC F_Q Surveillance Technical Specification, a more restrictive CAOC operating space may be implemented instead of a power reduction. A CAOC operating space is a unique combination of CAOC AFD band limits and control bank insertion limits. The COLR will include pre-analyzed CAOC operating spaces representing successively more restrictive operating spaces that provide commensurate improvements in F_Q margin for non-equilibrium operation.

If none of the CAOC operating spaces included in the COLR provides the required margin, new Required Action B.2.1 requires limiting the core thermal power to less than the RTP. The magnitude of the required

The first Frequency for SR 3.2.1.2 will be changed to state that $F_Q{}^W(z)$ must be verified to be within its limit following each refueling within 24 hours <u>after</u> achieving equilibrium conditions after thermal power exceeds 75% RTP. Some plant Technical Specifications have this Frequency in their TS (specifying 12 hours instead of 24 hours). This change is justified since initial startups following a refueling are slow and tightly controlled due to startup ramp rate limitations and fuel conditioning requirements. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q{}^W(z)$ limit. Also, core power distribution measurements taken at low powers (<50% RTP) to confirm that the core is loaded properly will provide ample indication that the core is operating consistent with expectations. The new Frequency will ensure that verification of $F_Q{}^W(z)$ is performed within a reasonable time period and prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged. Power levels of ≤ 75% RTP are non-limiting for minimum transient $F_Q{}^W(z)$ margin. Furthermore, as discussed in the previous section, surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75% power ensures that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium operation could be limiting. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

The second Frequency will be modified in the same ways as SR 3.2.1.1. In the improved F_Q TS, it will require verification of $F_Q{}^W(z)$ within 24 hours (instead of 12 hours) after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q{}^W(z)$ was last verified. As with SR 3.2.1.1, this Frequency of 24 hours is contained in some plant Technical Specifications. The Frequency of 24 hours is a reasonable time period in which to confirm that $F_Q{}^W(z)$ is within its limits given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

The second area for improvement of SR 3.2.1.2 concerns the note modifying SR 3.2.1.2. This note states the following:

"If measurements indicate that the maximum over z $[F_Q{}^C(z) / K(z)]$ has increased since the previous evaluation of $F_Q{}^C(z)$:

a. Increase $F_Q{}^W(z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q{}^W(z)$ is within limits or

b. Repeat SR 3.2.1.2 once per 7 EFPD until either a. above is met or two successive flux maps indicate that the maximum over z $[F_Q{}^C(z) / K(z)]$ has not increased."

The intent of this note in the current F_Q TS is to account for potential increases in $F_Q{}^W(z)$ between surveillances. It requires application of the greater of a 1.02 factor or a factor specified in the COLR (see Reference 5) whenever measurements indicate that the maximum value of $F_Q{}^C(z)/K(z)$ has increased. Alternatively, SR 3.2.1.2 must be repeated once per 7 EFPD until $F_Q{}^W(z)$ is within limits with the penalty factor applied or two successive flux maps indicate that $F_Q{}^C(z)/K(z)$ has not increased.

d. In accordance with the Surveillance Frequency Control Program.

These Frequencies permit power escalation following a refueling to no more than 75% RTP prior to performance of the first verification of $F_Q^C(z)$. They also require verification following large power level increases and periodically throughout the operating cycle. Together, these three Frequencies are unambiguous and appropriately verify $F_Q^C(z)$ during the initial power escalation and throughout the entire operating cycle until the next refueling outage. As discussed in subsection 3.2.4, the note modifying SR 3.2.1.1 has been eliminated. Also, the second Frequency has been increased from 12 to 24 hours. This Frequency of 24 hours is contained in some plant Technical Specifications and is a reasonable time period in which to perform this verification given the extremely small likelihood of limiting power shapes or limiting design basis events occurring prior to completion of the surveillance.

5.5 SURVEILLANCE REQUIREMENTS FOR $F_Q^W(Z)$

SR 3.2.1.2 requires verification that $F_Q^W(z)$ is within its limit. This is unchanged in the improved F_Q TS. As discussed in subsection 3.2.5, however, the Frequencies for SR 3.2.1.2 are changed relative to the current F_Q TS. The new Frequencies for SR 3.2.1.2 specify that $F_Q^W(z)$ must be verified to be within its limit as follows:

a. Once after each refueling within 24 hours after achieving equilibrium conditions after THERMAL POWER exceeds 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

The Frequencies in a. and b. are changed relative to the current F_Q TS.

In the current F_Q TS Frequency, the initial verification of $F_Q^W(z)$ following a refueling must occur prior to exceeding 75% power. In the improved F_Q TS, the initial verification must occur within 24 hours after achieving equilibrium after THERMAL POWER exceeds 75% RTP. This Frequency is contained in some plant Technical Specifications with 12 hours specified instead of 24 hours.

As discussed briefly in subsection 3.2.5, this change is justified for the following reasons:

1. Initial startups following a refueling are slow and tightly controlled due to startup ramp rate limitations and fuel conditioning requirements. Consequently, the initial startup following a refueling will not result in non-equilibrium power shapes that could challenge the $F_Q^W(z)$ limit.

2. Core power distribution measurements and physics testing performed at low powers (<50% RTP) confirm that the core is loaded properly and provide assurance that the core is operating consistent with expectations.

3. Surveillances at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. This was discussed in Section 3.1. The improved F_Q Surveillance formulation for RAOC plants mitigates this concern to some extent by largely eliminating sensitivity to ΔAO. Performing this initial verification after exceeding 75% power, however, ensures that the surveillance will be performed with appropriate steady state peaking factors measured at or near the power level and core conditions where future non-equilibrium operation has the potential for challenging fuel limits.

Power levels of ≤75% RTP are typically non-limiting for minimum transient $F_Q^W(z)$ margin because of the increase in the F_Q limit with reduced power. The new Frequency will ensure that verification of $F_Q^W(z)$ is performed prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could be challenged. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

The second Frequency was increased from 12 to 24 hours consistent with the change made to SR 3.2.1.1. Again, this Frequency is contained in some plant Technical Specifications.

As discussed in subsection 3.2.5, the note modifying SR 3.2.1.2 has been eliminated. The intent of this note in the current F_Q TS is to account for potential increases in $F_Q^W(z)$ between surveillances, which could be a month apart if the core is operating at RTP. It requires application of the greater of a 1.02 factor or a factor specified in the COLR whenever measurements indicate that the maximum value of $F_Q^C(z)/K(z)$ has increased. Alternatively, SR 3.2.1.2 must be repeated once per 7 EFPD until $F_Q^W(z)$ is within limits with the penalty factor applied or two successive flux maps indicate that $F_Q^C(z)/K(z)$ has not increased.

In the improved F_Q TS, the required penalty factor, R_j, is always applied, regardless of the trend in previous measurements. The R_j penalty factor is now simply part of the definition of $F_Q^W(z)$ (see expressions (5-1) and (5-2)) and is determined in the same manner as for the current F_Q TS (Reference 5). The COLR will provide the required penalty factors as a function of cycle burnup. Required penalty factors will be provided for each ROS. When margin is predicted to increase in the upcoming operating period, the COLR will indicate a penalty factor of 1.0, i.e., no penalty. A penalty factor greater than 1.0 will be required whenever the <u>minimum margin</u> to the $F_Q^W(z)$ limit is predicted to decrease in the upcoming period.

In the current F_Q TS, the application of the penalty factor for the next operating period is predicated upon an increase in the measured value of $F_Q^C(z)/K(z)$ over the <u>previous</u> operating period.. While a change in measured $F_Q^C(z)/K(z)$ is a good figure of merit for margin changes, the improved F_Q TS is more appropriate and rigorous since future decreases in margin are the relevant concern and are directly employed in determining whether a penalty is necessary. This avoids any lag in the application of the penalty factor caused by the requirement for two successive measurements, which could be a month or more apart, to indicate a decrease in margin. Therefore, the revised note will better capture the expected trend of the margin based on predictions. By eliminating the note, however, the option to perform more frequent surveillances in lieu of applying the penalty factor is also eliminated. It will be necessary to demonstrate that the LCO is met with the COLR R_j factor applied. If the LCO is not met, then the Required Actions must be performed to restore margin. The current F_Q TS, requires a minimum penalty of

Actions B.2.2 and B.2.3 are consistent with the current F_Q TS and the improved RAOC F_Q TS whenever a reduction in the maximum allowable power is specified. They are conservative measures that provide protection against the consequences of Condition II transients in light of the larger local peaking factors that caused $F_Q^W(z)$ to exceed its limit. Required Action B.2.4 is essentially the same as in the current F_Q TS except that the Completion Time has been specifically tied to Required Action B.2.1, which specifies the required limit on thermal power.

The Required Action for Condition C, "Required Action and Completion Time not met," is unchanged in the improved CAOC F_Q TS. The Required Action is to be in MODE 2 within 6 hours.

8.4 SURVEILLANCE REQUIREMENTS FOR $F_Q^C(Z)$

The Surveillance Requirements for $F_Q^C(z)$ for the improved CAOC F_Q TS are the same as for the improved RAOC F_Q TS. SR 3.2.1.1 requires verification that $F_Q^C(z)$ is within its limit, and the current Frequencies for SR 3.2.1.1 specify that $F_Q^C(z)$ must be verified to be within its limit as follows:

a. Once after each refueling prior to THERMAL POWER exceeding 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^C(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

These Frequencies were briefly discussed in Section 5.4 for the improved RAOC F_Q TS.

8.5 SURVEILLANCE REQUIREMENTS FOR $F_Q^W(Z)$

The Surveillance Requirements for $F_Q^W(z)$ for the improved CAOC F_Q TS are the same as for the improved RAOC F_Q TS. These new Frequencies for SR 3.2.1.2 specify that $F_Q^W(z)$ must be verified to be within its limit as follows:

a. Once after each refueling within 24 hours after achieving equilibrium conditions after THERMAL POWER exceeds 75% RTP; and

b. Once within 24 hours after achieving equilibrium conditions after exceeding, by ≥ 10% RTP, the THERMAL POWER at which $F_Q^W(z)$ was last verified; and

c. 31 EFPD thereafter; or

d. In accordance with the Surveillance Frequency Control Program.

The discussion provided in Section 5.5 for the improved RAOC F_Q TS applies to the improved CAOC F_Q TS, including the calculation and application of the R_j margin decrease factors. Refer to Section 5.5 for details on these factors.

implemented for future operation that provides the required additional transient F_Q margin. In the unlikely event that no RAOC operating space provides the required margin improvement, then thermal power and AFD restrictions defined in the COLR are required.

The improved CAOC F_Q Surveillance TS also incorporates the concept of operating spaces. The current CAOC F_Q Surveillance TS requires a power level reduction if the F_Q limit is exceeded. The improved F_Q TS provides the option of implementing a more restrictive CAOC operating space, which is defined as a unique combination of AFD band and Control Bank Insertion Limits. As in the improved RAOC F_Q Surveillance TS, the CAOC operating spaces are specified in the COLR.

Both the improved RAOC and CAOC F_Q Surveillance TSs modify the surveillance Frequencies of the TS by requiring that the first surveillance of $F_Q^W(z)$ following a refueling be performed after achieving equilibrium conditions above 75% RTP. Performing this initial verification after exceeding 75% RTP ensures that the surveillance will be performed with the more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium operation could be limiting. If the surveillance indicates that future non-equilibrium operation could challenge the limit, the Required Actions in the improved F_Q TS will provide appropriate compensatory measures to ensure that the LCO will be met during such operation.

Finally, a minor improvement was made to the manner in which potential decreases in the transient F_Q margin between surveillances are addressed. In the improved F_Q TS, application of an $F_Q^W(z)$ penalty factor included in the COLR will be required regardless of the previous measurement trend. When margin is predicted to decrease, the COLR will indicate a penalty factor that is greater than 1.0. If margin is predicted to increase, no penalty is required (the COLR penalty factor is 1.0). Thus, the application of the penalty factor is tied to a predicted decrease in the actual transient F_Q margin in the upcoming surveillance period rather than an increase in the measured value of $F_Q^C(z)/K(z)$ over the previous surveillance period. This is more appropriate and rigorous since future decreases in margin are the relevant concern.

It is anticipated that implementation of these new formulations and TSs will lead to more accurate transient F_Q margin assessments and more appropriate compensatory measures in the unlikely event that limits are exceeded.

APPENDIX H
EDITORIAL CHANGES TO THE FINAL SAFETY EVALUATION

In addition, there is a NOTE which modifies the SR as follows:

> "If measurements indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has increased since the previous evaluation of $F_Q^C(Z)$:
>
> (1) Increase $F_Q^W(Z)$ by the greater of a factor of [1.02] or by an appropriate factor specified in the COLR and reverify $F_Q^W(Z)$ is within limits or
>
> (2) Repeat SR 3.2.1.2 once per 7 EFPD until either a., above, is met, or two successive flux maps indicate that the maximum over Z [$F_Q^C(Z)$/K(Z)] has not increased."

The revised SR 3.2.1.2 modifies the first and second Frequency (items (1) and (2) above) and eliminates the NOTE.

The first Frequency is modified to be conducted following each refueling within [24] hours after thermal power exceeds 75 percent RTP.[5] This change is justified based on multiple reasons:

- Initial startups are not expected to result in non-equilibrium power shapes that could challenge the $F_Q^W(Z)$ limit since initial startups are slow and are generally tightly controlled due to startup ramp rate limitations and fuel conditioning requirements.

- Core power distribution measurements taken at low power (<50 percent RTP) to confirm that the core is loaded properly will provide ample indications that the core is operating consistent with the expectations.

- Surveillances performed at low power levels can be challenging with respect to obtaining an accurate transient F_Q margin assessment. Performing this initial verification after exceeding 75 percent RTP will ensure that the surveillance will be performed with more appropriate steady state peaking factors measured at or near the power level where future non-equilibrium conditions could be limiting.

- Power levels of ≤ 75 percent RTP are non-limiting for minimum transient $F_Q^W(Z)$ margin. Performing the surveillance within 24 hours after thermal power exceeds 75 percent RTP will assure verification prior to extended non-equilibrium operation at power levels where the maximum permitted peak linear heat rate could potentially be challenged.

The second Frequency is modified in the same way as SR 3.2.1.1 discussed earlier. It is proposed to require verification of $F_Q^W(Z)$ within 24 hours (instead of 12 hours) after achieving the equilibrium conditions after exceeding, by ≥ 10 percent RTP, the THERMAL POWER at which $F_Q^W(Z)$ was last verified. The Frequency of 24 hours is considered a reasonable time period in which to confirm that $F_Q^W(Z)$ is within its limits given the extremely small likelihood of

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[5] In Reference 7, a final modification was made to this Frequency to eliminate the italicized portion of the phrase "...within [24] hours *after achieving equilibrium conditions* after thermal power..."

}.

The TR introduces the $A_{XY}(Z)$ and $A_Q(Z)$ factors defined in Equations (6) and (8), respectively, to adjust for a change in radial peaking factor due to difference in power level and control rod insertion relative to the reference core condition. In practice, the $A_{XY}(Z)$ and $A_Q(Z)$ factors allow for a slight adjustment, usually a reduction, in the calculated $F_Q^W(Z)$, when the $F_Q^W(Z)$ surveillance is conducted { }.
This factor is evaluated in detail in Section 4.1.1 of this SE.

The use of the measured $F_{XY}(Z)$ rather than $F_Q(Z)$ is an important part of the new RAOC formalism. Examples of measurements from different reactors are shown in WCAP-17661 and although measurement of $F_{XY}(Z)$ can be problematic in planes where grids reside, this is not an issue, because grid plane regions are excluded from surveillance as noted below. Section 4.4 of WCAP-17661 notes that the regions where there are measurement exclusions continue to be:

- Lower core region, generally[6] from 0 percent to 15 percent inclusive
- Upper core region, generally[7] from 85 percent to 100 percent inclusive
- Grid plane regions, ±2 percent inclusive
- Core plane regions, within ±2 percent of the bank demand position of the control banks

The use of the uncertainty factor U_F to account for both measurement and fuel manufacturing uncertainties was questioned (RAI No. 4) as it was not clear why a manufacturing uncertainty was needed. The RAI also questioned how the uncertainty in T(Z) was taken into account. The response to the RAI explains that the uncertainties used are conservative. The manufacturing (or engineering) uncertainty was originally introduced because the "measured" $F_Q(Z)$ in the formulation is a pin (i.e., fuel rod) power whereas the actual measurement is a fuel assembly power. The fuel manufacturing uncertainty is needed to account for pin-to-assembly factors[7] that compensate for this difference. Since the measurement already accounts for actual, as-manufactured conditions, this is not important. Furthermore, since the definition of the T(Z) factor is based on bounding calculations, it is not necessary to introduce additional uncertainty for this factor. Hence, it is concluded that the approach to uncertainty in the improved methodology is sufficiently conservative.

The last factor in Equation (4) is a penalty that is related to the elimination of the NOTE for SR 3.2.1.2. The NOTE (see also Section 4.4) required certain actions take place when the maximum over Z of $F_Q^C(Z)/K(Z)$[8] increased relative to the previous surveillance. The concern at the introduction of this requirement was deviations between measured and predicted steady state power shapes due to integral fuel burnable absorber-induced power shift (also known as axial offset deviation, AOD) or crud induced power shift (CIPS) both of which occur slowly over

[6] Per Footnote 4 on Page 3, the plant- or cycle-specific exclusion regions may be different.
[7] As noted in the RAI response, these pin-to-assembly factors account for the fact that the analytically derived pin factors are based on nominal design characteristics such as pellet enrichment, density, and burnable absorber loading. The engineering uncertainty addresses the effects of variations in the as-built fuel pellet from such nominal values.
[8] K(Z) is a function that defines the axial dependence of the acceptable value of F_Q.

ensure that the plant has time to restore equilibrium conditions in the event that control rod motions result in transient conditions.

In Topic (b) of RAI 5, the NRC staff determined that, to remain in the operating space defined by Required Action B.1, the operators would need to have a clear understanding that the margin improvement is being maintained. Additional information for the operator may be needed to determine if Required Action B.1 is sufficient or Required Actions B.2 are necessary. The NRC staff requested justification as to why a tabular presentation of the margin improvement as a function of the axial position or some other scheme in the COLR would not be required.

The response to RAI 5(b) stated that the margin can be determined by applying the new surveillance factors associated with the revised operating space to the power distribution measurement. Additionally, the response noted that $F_Q^C(Z)$ and $F_Q^W(Z)$ surveillances would now be required in the event that implementation of a new operating space requires control rod motion. Thus, performance of the SRs would provide the necessary margin confirmation. The NRC staff agrees with the response, since the concern was related to the implementation of new operating spaces in conjunction with control rod motion, which would require the performance of SRs 3.2.1.1 and 3.2.1.2.

Topic (d) of RAI 5 addresses the actions that will be taken by the operators to remedy potential violations of the newly implemented operating space associated with Required Action B.1. The response identified other TS Required Actions and SRs that would apply in such a situation, particularly with regard to control rod insertion limits and position. Because the potential for violation of the core operating limit parameters for an operating space can be addressed through existing TS Required Actions and SRs, the NRC staff determined that the response addressed the concern indicated in RAI 5d acceptably.

The improved methodology allows for the use of new operating spaces, as defined in the COLR. The addition of Required Action B.1.2 assures that for situations involving control rod movement SRs 3.2.1.1 and 3.2.1.2 will be performed to ensure that $F_Q^C(Z)$ and $F_Q^W(Z)$ remain within limits. Based on the review described above, the NRC staff determined that the proposed Required Actions B.1 are acceptable.

4.3.2 Required Action B.2 and Limitation on Thermal Power

The improved TSs define a new Required Action B.2 which includes four actions (B.2.1, B.2.2, B.2.3, and B.2.4). If the RAOC or CAOC operating spaces defined in the COLR are insufficient to ensure margin to the $F_Q^W(Z)$ limits, then the Required Actions B.2 are entered. The actions involve reducing the thermal power to less than the thermal power specified in the COLR along with reduction of the setpoints. For more explicit presentation of the changes and associated justifications, see Table 2.

The issues addressed in the review of these changes related to the change of the thermal power level. As noted in WCAP-17661-P, the reductions in the thermal power levels evaluated and included in the COLR. If the required margin improvement exceeds the level of pre-analyzed thermal power limits, then the option is to limit the thermal power to < 50 percent RTP. The 50 percent RTP applies to all Westinghouse plants that implement this TR and no plant-specific evaluations are involved. However, the response to RAI 7 stated that the 50 percent value is consistent with the required power reduction associated with other

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