ATTACHMENT 4

WCAP-17661-P/ WCAP-17661-NP, Revision 1

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(Non-Proprietary)

(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 ≥ 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 previous 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 ~~after 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 $\leq$ 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 $\geq$ 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 <u>prior</u> 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.~~ 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.

~~3.~~ 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 minimum margin 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 previous 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~~ 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.