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SAFETY EVALUATION SUPPORTING A MORE NEGATIVE EOL MODERATOR TEMPERATURE COEFFICIENT TECHNICAL SPECIFICATION FOR THE ALVIN W. VOGTLE NUCLEAR PLANT UNITS 1 AND 2

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ABSTRACT

This report proposes a relaxation of the Limiting Condition for Operation and Surveillance Requirements values of Moderator Temperature Coefficient for the end of cycle, rated thermal power condition. Relaxation is sought in order to improve plant availability and minimize disruptions to normal plant operation, while continuing to satisfy plant safety criteria. A methodology for establishing Technical Specification end of cycle Moderator Temperature Coefficient values that are consistent with the plant safety analyses is described herein. Specific application of the methodology to the Alvin W. Vogtle Nuclear Plant Units 1 and 2 provides Technical Specification Moderator Temperature Coefficient values which are proposed to replace the existing values.

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1.0 INTRODUCTION

1.1 Background

For FSAR accident analyses, the transient response of the plant is dependent on reactivity feedback effects, in particular, the moderator temperature coefficient (MTC) and the Doppler power coefficient. Because of the sensitivity of accident analyses results to the MTC value assumed, it is important that the actual core MTC remain within the bounds of the limiting values assumed in the FSAR accident analyses. While core neutronic analyses will have predicted that the MTC is within these bounds, the Technical Specifications require that the core MTC also be confirmed by measurement, as verification of the accuracy of the neutronic predictions. These MTC measurements are performed:

1. At beginning of cycle, prior to initial operation above 5% power, and

2. Within 7 EFPD after reaching an equilibrium boron concentration of 300 ppm.

1.2 Basis of Current EOL MTC LCO and SR Values

In order to ensure a bounding accident analysis, the MTC is assumed to be at its most limiting value for the analysis conditions appropriate to each accident. Currently, the most negative MTC limiting value is based on EOL conditions (specifically with regards to fuel burnup and boron concentration), full power, with rods fully inserted. Most accident analyses use a constant moderator density coefficient (MDC) designed to bound the MDC at this worst set of initial conditions (as well as at the most limiting set of transient conditions). This value for MDC forms the licensing basis for the FSAR accident analysis.

Converting the MDC used in the accident analyses to a MTC is a simple calculation which accounts for the rate of change of moderator density with temperature at the conditions of interest. In this report, the convention followed is to discuss the moderator feedback in terms of MTC, rather than MDC. Nevertheless, it is important to note that the accident analyses actually assume a constant MDC value, rather than making any explicit assumption on MTC.

Technical Specifications place both Limiting Condition for Operation (LCO) and Surveillance Requirements (SR) values on MTC, based on the accident analysis assumptions on MDC described above. The most positive MTC LCO limit applies to Modes 1 and 2, and requires that the MTC be less positive than the specified limit value. The most negative MTC LCO limit applies to Modes 1, 2, and 3, and requires that the MTC be less negative than the specified limit value for the all rods withdrawn, end of cycle life, rated thermal power condition.

The Technical Specification SR calls for measurement of the MTC at BOL of each cycle prior to initial operation above 5% rated thermal power, in order to demonstrate compliance with the most positive MTC LCO. Similarly, to demonstrate compliance with the most negative MTC LCO, the Technical Specification SR calls for measurement of the MTC prior to EOL (near 300 ppm equilibrium boron concentration). However, unlike the BOL situation, this 300 ppm SR MTC value differs from the EOL LCO limit value. Because the HFP MTC value will gradually become more negative with further core depletion and boron concentration reduction, a 300 ppm SR value of MTC should necessarily be less negative than the EOL LCO limit. The 300 ppm SR value is sufficiently less negative than the EOL LCO limit value to provide assurance that the LCO limit will be met when the 300 ppm surveillance criterion is met.

1.3 Operational Considerations: EOL MTC Tech Spec SR Value

It is becoming increasingly probable that reload cores will fail to meet the current 300 ppm surveillance criterion associated with the EOL LCO limit. The primary factors causing more negative MTCs near EOL are higher core average operating temperature and higher discharge burnup. Failure to meet the surveillance criterion does not by itself imply a failure to meet the actual EOL MTC limit stated in the LCO, but invokes the requirement that the HFP MTC continue to be measured at least once per 14 EFPD during the remainder of the fuel cycle. This repeated surveillance is performed to demonstrate that the actual LCO limit on EOL MTC is not violated.

The drawbacks to the current EOL MTC Surveillance Criterion are:

1. The current and planned fuel management strategy is expected to yield MTC values which will be more negative than the existing 300 ppm surveillance criterion. This would result in repeated MTC measurements every 14 EFPD. In addition, the EOL HFP ARO MTC values for these anticipated designs will approach the existing LCO limit.

2. If repeated measurements are necessary, they can require that load swings be performed, causing temperatures to deviate from the programmed reference temperature - situations which are never preferable to nominal steady state operation.

3. The repeated measurements require the resources of multiple operations personnel for roughly an entire shift, and require greater water processing for measurement via the boration/dilution method.

Westinghouse-designed PWRs which conform to Standard Technical Specification (STS) format (including the A. W. Vogtle Units 1 and 2 Technical Specifications) generally feature a 300 ppm SR MTC value which is 9 pcm/°F less negative than the EOL LCO limit on MTC. Given the disadvantages of repeating the MTC plant measurements, it is logical to inquire if this difference between the SR value and the LCO value is overly large, and would possibly invoke repeated measurements which are unnecessary.

Examination of both plant-specific characteristics and fuel management effects on the difference between the 300 ppm HFP ARO predicted MTC and the EOL (0 ppm) HFP ARO predicted MTC indicates that the 9 pcm/°F difference applied to Westinghouse-designed STS plants is very conservative. This implies that a failure to satisfy the 300 ppm surveillance criteria can occur, yet the actual EOL MTC value could show margin to the LCO limit. It is concluded that relaxation of the difference between the SR limit value and the LCO limit value should be investigated, so as to preclude unnecessary MTC testing at full power conditions.

1.4 Operational Considerations: EOL MTC Tech Spec LCO Value

Relaxation of the SR limit value may provide only temporary relief from the repeated MTC measurement situation. With longer operating cycles and increased fuel discharge burnups, future reload core designs may eventually challenge the EOL MTC LCO limit. The reload core design process would detect the fact that the design value of EOL MTC could exceed the Tech Spec LCO limit long before a reload core were to begin operation. There are design measures that can be taken to produce a less negative EOL MTC but they negatively impact fuel cycle energy and operability and may lead to more positive MTC values at the beginning of cycle.

The FSAR accident analyses which form the plant's licensing basis have assumed a MDC value which, when converted to a MTC at full power pressure and temperature, translates to a HFP MTC value that is more negative than the LCO limit value of the Technical Specifications. The difference between the value of most negative MTC (most positive MDC) assumed in the accident analyses and that presented as the LCO of the Tech Specs is substantial, and offers a potential avenue for relaxation of the Tech Spec EOL MTC LCO value. The thrust of such an effort to relax the EOL MTC Tech Spec LCO limit must continue to bound the accident analysis assumptions, and should establish a reasonable basis for the difference between the safety analysis value of most negative MTC and the Tech Spec LCO value.

2.0 METHODOLOGY FOR MODIFYING MOST NEGATIVE MTC TECH SPEC VALUES

2.1 Conversion of Safety Analysis MDC to Tech Spec MTC

As stated previously, the FSAR accident analyses have assumed a bounding value of the moderator density coefficient (MDC) which ensures a conservative result for the transient analyzed. The process by which the accident analysis most positive MDC is transformed into the most negative MTC LCO value is stated in STS BASES section 3/4.1.1.3:

> "The most negative MTC, value equivalent to the most positive moderator density coefficient (MDC), was obtained by incrementally correcting the MDC used in the FSAR accident analyses to nominal operating conditions. These corrections involved subtracting the incremental change in the MDC associated with a condition of all rods inserted (most positive MDC) to an all rods withdrawn condition and, a conversion for the rate of change of moderator density with temperature at RATED THERMAL POWER conditions. This value of the MDC was then transformed into the limiting MTC value."

In the process of converting the accident analysis MDC into the Tech Spec MTC, the conversion for the rate of change of moderator density with temperature at rated thermal power conditions involves conventional thermodynamic properties and imposes no undue conservatism on the resulting MTC value. The additional conversion made is to correct the above MDC (MTC) value for the change associated with going from a condition of ARI to one of ARO. That is, the accident analysis MDC (MTC) assumes a coefficient determined for a condition of EOL HFP 0 ppm with all control and shutdown banks fully inserted. This accident analysis MDC (MTC) is corrected back to the ARO condition, in order to produce a Tech Spec limit which permits direct comparison against measured values. The effect of the presence of all control and shutdown banks is to make the MTC for the ARI condition markedly more negative than a MTC at the ARO condition, hence this conversion has a substantial impact.

2.2 Conservatism of the ARI to ARO MTC Conversion

The use of a substantially negative MTC (positive MDC) value for the transient accident analyses is prudent, in that it produces a more severe result for the transient, which makes the analysis inherently conservative. The drawback to the ARI assumption is that when the conversion to the ARO condition is made, the resulting Tech Spec MTC value is dramatically less negative than the value corresponding to the transient safety calculations, and is even less negative than the expected best estimate values of EOL MTC for high discharge burnup reload cores. In the worst case, maintaining the EOL MTC Tech Spec limit at its present value could result in requiring that the plant be placed in hot shutdown when, in fact, there exists substantial margin to the moderator coefficient assumed in the accident analyses. Such a situation is unnecessarily restrictive, and results primarily from the ARI to ARO adjustment made between the accident analysis MDC value and the Tech Spec MTC value.

In addition to being unnecessarily restrictive, the HFP ARI assumption is inconsistent with Tech Spec requirements for allowable operation, wherein shutdown banks are not permitted to be inserted during power operation and control banks must be maintained above their insertion limits.

2.3 Alternative MTC Conversion Approach

If the ARI to ARO basis for converting from the accident analysis MDC value to a Tech Spec LCO MTC value is overly restrictive, what would constitute a more meaningful, yet inherently conservative basis? The concept herein proposed as an alternative to the ARI to ARO conversion is termed the "Most Negative Feasible MTC" approach. This approach maintains the existing accident analysis assumption of a bounding value of moderator coefficient, but offers an alternative method for converting to the Tech Spec LCO MTC value.

The Most Negative Feasible MTC approach seeks to determine the conditions for which a core will exhibit the most negative MTC value that is consistent with operation allowed by the Tech Specs. As an example, the Most Negative Feasible MTC approach would not require a conversion assumption that all rods be fully inserted at HFP conditions, but would require a conversion assumption that all control banks are inserted the maximum amount that Tech Specs permit, so as to make the calculated EOL HFP MTC more negative than it would be for an unrodded core.

The Most Negative Feasible MTC approach determines EOL MTC sensitivity to those design and operational parameters which directly impact MTC, and attempts to make this determination in such a manner that the resulting sensitivity for one parameter is independent of the assumed values of the other parameters. As a result, parameters which are mutually exclusive but permissible according to the Tech Specs (such as an assumption of full power operation and an assumption of no xenon concentration in the core), and which serve to make MTC more negative, will have their incremental impacts on MTC combined to arrive at a conservative and bounding condition for the most negative feasible MTC. The parameters which are variable under normal operation, and which affect MTC are:

- soluble boron concentration in the coolant
- moderator temperature and pressure
- RCCA insertion
- axial flux (power) shape
- transient fission product (xenon) concentration

The Most Negative Feasible MTC approach examines each parameter separately, and assesses the impact of variation in that parameter on EOL MTC. The assessment is performed for multiple core designs that feature combinations of fuel design, discharge burnup, cycle length, and operating temperature expected to envelope future core designs of the plant of interest.

When the assessment is complete, the MTC sensitivity associated with each of the above parameters will have been identified. One then determines the maximum deviation from "nominal" conditions (ARO, HFP, equilibrium xenon, Tavg on the reference temperature program) that the Tech Specs permit, and multiplies that deviation by the appropriate MTC sensitivity to arrive at a "delta MTC" factor associated with the parameter. For example, suppose it is determined that the MTC becomes 1 pcm/°F more negative for each 1°F increase in core average operating temperature above nominal (the MTC "sensitivity" is -1 pcm/°F/°F). If the Tech Specs permit a maximum increase in Tavg of 4°F above nominal core Tavg, then the moderator temperature "delta MTC" factor is:

$$(-1 \text{ pcm/°F/°F}) \times 4\text{°F} = -4 \text{ pcm/°F}.$$

Bounding "delta MTC" factors are determined in this way for each of the above paramete[illegible] and these factors are then added to arrive at an overall bounding "delta MTC" factor. This overall "delta MTC" factor states how much more negative the MTC can become, relative to the nominal EOL HFP ARO MTC value, for normal operation scenarios permitted by the current Tech Specs. The conditions of moderator temperature, rod insertion, xenon, etc., which defined the Most Negative Feasible MTC condition become the conversion proposed as a replacement for the ARI to ARO conversion of the current MTC Tech Spec. The conversion for the Most Negative Feasible MTC condition is applied in the same way that the current ARI-to-ARO conversion is applied, in order to arrive at an EOL ARO HFP MTC Tech Spec limit which remains based on the accident analysis MDC assumption.

2.4 Determining SR MTC from LCO MTC

Under the Most Negative Feasible MTC approach, the 300 ppm surveillance value is determined in the manner currently stated in the BASES for STS plant MTC Tech Specs:

> "The MTC surveillance value represents a conservative value (with corrections for burnup and soluble boron) at a core condition of 300 ppm equilibrium boron concentration and is obtained by making these corrections to the limiting MTC LCO value."

That is, the 300 ppm surveillance value is derived by making a conservative adjustment to the EOL ARO HFP MTC limit value that accounts for the change to MTC with soluble boron and burnup. Plant-specific examination of the difference between 300 ppm HFP MTC and EOL (0 ppm) HFP MTC suggests that a smaller correction is justified than the 9 pcm/°F which has historically been applied to Westinghouse-designed STS plants.

2.5 Benefits of the Alternative MTC Conversion Approach

The Most Negative Feasible MTC approach is considered to be superior to the ARI-to-ARO conversion specified by current STS plant Tech Specs for the following reasons:

1. The Most Negative Feasible MTC approach results in a relaxed surveillance limit which significantly reduces the probability of having to perform repeated MTC surveillance measurements. Such repeated measurements are undesirable because they entail perturbations to normal reactor operation and they are costly.

2. The Most Negative Feasible MTC approach does not alter the FSAR transient accident analysis bases or assumptions, and hence, does not affect the accident analysis conclusions. It retains the concept of a conversion between the accident analysis MDC assumption and the Tech Spec LCO MTC value that assures that the plant cannot experience a MDC which is more severe than that assumed in the accident analyses.

3. The Most Negative Feasible MTC condition is a conservative but reasonable basis to assume for a MTC value of the reload core prior to a transient, and is consistent with operation as defined by other sections of the Tech Specs (whereas the ARI-to-ARO conversion is overly conservative and makes assumptions which are inconsistent with other sections of the Tech Specs).

Additionally, the Most Negative Feasible MTC approach retains the "built-in safeguard" of a requirement for a 300 ppm surveillance measurement to be performed in order to verify that the reactor is operating in a regime that is bounded by the accident analysis input assumptions.

3.0 MOST NEGATIVE FEASIBLE MTC APPROACH APPLIED TO A. W. VOGTLE UNITS 1 AND 2

3.1 A. W. Vogtle Units 1 and 2 Accident Analysis MDC Assumption

The FSAR accident analyses upon which the Tech Spec EOL HFP LCO MTC limit is based have assumed bounding values of moderator density coefficient in order to ensure a conservative simulation of plant transient response for the A. W. Vogtle Nuclear Plant units. For those transients for which analysis results are made more severe by assuming maximum moderator feedback, a moderator density coefficient (MDC) of 0.43 Δk/gm/cc has been assumed to exist throughout the transient.

When discussing the Tech Spec EOL LCO limit on moderator feedback, it is simpler to talk in terms of moderator temperature coefficient (MTC) than MDC. For this reason, the A. W. Vogtle accident analysis MDC assumption of 0.43 Δk/gm/cc is converted to its equivalent MTC. This conversion depends on the density change-to-temperature change relationship which prevails for the conditions of interest. For this discussion, the conditions of interest are the core temperature and pressure (hence, density) experienced under normal operation at which the MDC assumes its most extreme (positive) value. These temperature and pressure conditions are the A. W. Vogtle unit's full power, full flow nominal core operating conditions of 591.8°F and 2250 psia, respectively.

At these nominal HFP operating conditions, the accident analysis MDC value of 0.43 Δk/gm/cc is equivalent to a HFP MTC of -56 pcm/°F. For simplicity, this value of MTC will often be referred to as the "accident analysis MTC", in the discussion which follows. However, it should be remembered that the applicable accident analyses actually assume a constant MDC value of 0.43 Δk/gm/cc and make no explicit assumption about MTC.

3.2 Determination of Most Negative Feasible MTC Sensitivities

As stated previously, there are a limited number of core operational parameters that directly affect MTC and are variable under normal core operation. The list of parameters is as follows.

- soluble boron concentration in the coolant
- moderator temperature and pressure
- RCCA insertion
- axial flux (power) shape
- transient fission product (xenon) concentration

The radial flux (power) shape can also vary under normal core operation and will affect MTC. However, the operational activities that directly affect radial power shape do so through withdrawal or insertion of control rods and through xenon concentration; therefore, the impact of radial flux distribution variation on MTC will be an implicit part of the MTC sensitivity to these other parameters.

Soluble boron concentration is certainly variable under normal core operation. However, it is eliminated as a source of sensitivity for this analysis. This is because the EOL HFP ARO MTC Tech Spec limit value is assumed to be essentially a 0 ppm limit by virtue of the definition of EOL. The most negative MTC value will always occur at a boron concentration of 0 ppm, and therefore, a 0 ppm boron concentration is assumed as the basis of the EOL MTC Tech Spec limit under the Most Negative Feasible MTC approach.

For the remaining parameters, sensitivity analyses were performed by perturbing the parameter of interest in such a way as to induce a change from its nominal EOL value, and then performing a MTC determination with the parameter held in the perturbed state. A further perturbation was induced and the MTC calculation repeated. This sequence was repeated until sufficient MTC data values were generated to reliably determine the trend of MTC change with variation in the value of the independent parameter.

In order to establish trends in MTC that are appropriate [ ]+a, c for the A. W. Vogtle unit's reload cores, these sensitivity calculations were performed for three different Vogtle reload cores. These cores exhibit fuel and core design features that currently exist, and changes that are anticipated in future A. W. Vogtle reload cores. The MTC values of future designs may become more negative than current Vogtle reload cores. A brief description of the Vogtle reload core designs follows, these correspond to Vogtle Unit 1, however, they represent Vogtle Unit 2 fuel management as well.

RELOAD A: This core is the initial Vogtle Unit 1 reload core (Cycle 2). It utilizes the Westinghouse 17x17 fuel design and operates at a nominal core average moderator temperature of 591.8° F (3411 MWt). The cycle length is 427 effective full power days (EFPD). The reload uses a low leakage loading pattern fuel placement arrangement. The discharge region burnup is necessarily low, as it is the first reload. The control rod absorber material is hafnium.

The second Vogtle reload core (Cycle 3) incorporates the same fuel management, and core conditions. Sensitivity calculations were performed for this core, with similar results as Cycle 2.

RELOAD B: This core is the conceptual first transition reload cycle for A. W. Vogtle Unit 1. It utilizes the Westinghouse 17x17 OFA(1) fuel design and operates at uprated core conditions corresponding to 3565 MWt. The cycle length is 480 EFPD. The reload uses a low leakage loading pattern fuel placement arragement. The anticipated region average discharge burnup of the feed fuel is just over 45,000 MWD/MTU.

RELOAD C: This core is the second transition reload cycle for A. W. Vogtle Unit 1. It utilizes the Westinghouse OFA fuel design and operates at the uprated core conditions. The cycle length is 480 EFPD. The reload uses a low leakage loading pattern fuel placement arrangement. The discharge region average burnup is approximately 45,000 MWD/MTU.

Reloads B and C may charge to Silver-Indium-Cadmium control rods. The neutronic effects have been explicitly accounted for in the core models. The A. W. Vogtle control bank configuration that is used is shown in Figure 3.1.

The core neutronic models of these three reload cores were derived using standard Westinghouse procedures and computer methods. The ARK code, which has evolved from the LEOPARD[(2)] and CINDER[(3)] codes, was used to perform the fast and thermal spectrum calculations and is the basis for all cross sections, depletion rates, and reactivity feedback models. ANC[(4)], a nodal analysis theory code that is used in two and three dimensions, was used for core neutronic calculations to determine MTC sensitivity for the three reload cores. APOLLO, an advanced version of PANDA[(5)], was used as an axial neutronic model of the reload cores to determine MTC sensitivity to varying axial flux shape.

The neutronic calculations performed for the three reload core designs established MTC sensitivities for each of the parameters listed above. The detailed description and results of these calculations are provided in Appendix A.

3.3 Maximum Allowed Deviations from Nominal Operating Conditions

The concept of maximum allowed deviation from nominal operating conditions is employed to determine the extent to which reactor parameters can vary under normal operation so as to cause MTC to become more negative. This combination of parameter statepoints then defines the worst allowable initial condition for a transient which employs a most negative MTC (most positive MDC) assumption. It is also necessary to demonstrate that the parameter changes that occur throughout the transient do not result in a MTC value which is unbounded by the constant moderator coefficient assumption used in the accident analysis. The adequacy of the constant MDC accident analysis assumption to bound MTC values that occur throughout the transient is examined in detail in Section 4.

The bases for the maximum allowed deviation from nominal operating conditions are Technical Specifications that limit the extent of moderator temperature increase, RCCA insertion, and axial power skewing. The deviations permitted by present A. W. Vogtle Tech Specs and possible future perturbations to those Tech Specs values are discussed in the following sections:

Moderator Temperature and Pressure Deviations

Tech Spec 3.2.5 establishes the LCO values of the DNB parameters reactor coolant system Tavg and pressurizer pressure. This section of the A. W. Vogtle Tech Specs is excerpted and presented in Appendix B.

Tech Spec 3.2.5 states a minimum allowable pressurizer pressure of 2224 psig, and the maximum allowable RCS average temperature of 591°F. This value is expected to increase to 592.5°F with OFA fuel, at uprated core conditions. Accounting for the instrumention uncertainty, this temperature is further increased to 594.4°F. Because the nominal operating RCS temperature for the A. W. Vogtle units is 588.5°F, the 594.4°F Tech Spec limit represents a 5.9°F maximum allowable Tavg increase over nominal conditions. This allowable temperature increase is changed to 7.2° F to account for possible increases in Tavg with respect to RCS Temperature. The current nominal design pressure for the A. W. Vogtle units is 2250 psia; this value is reduced by a conservative maximum control uncertainty of 50 psi. Therefore, the resulting 2200 psia system pressure is conservative with respect to the 2224 psig Tech Spec limit.

Because there are limits on the deviations from nominal condition RCS temperature and pressure of +7.2°F and -50 psi, respectively, there are also implicit limits on the maximum allowable deviation of RCS moderator density from nominal. These maximum temperature and pressure deviations are applied to the MTC sensitivity to temperature and pressure, which is described in Appendix A, to obtain a "delta MTC" factor associated with RCS moderator temperature and pressure deviations from nominal. The resulting "delta MTC" is [ ]$^{+a,c}$ pcm/°F.

RCCA Insertion Deviation

The nominal condition assumption for RCCA placement is complete withdrawal (ARO). This assumption is underscored by the requirement in Tech Spec 3.1.1.3 (see Appendix B) that the LCO value of EOL MTC is for the "all rods withdrawn" condition. Because some RCCA insertion is allowed during full power operation, and because RCCA insertion will generally cause MTC to be more negative than it would be otherwise, the RCCA insertion deviation is simply that maximum allowable RCCA insertion permitted by the Tech Specs.

Tech Specs 3.1.3.5 and 3.1.3.6 place limits on allowable RCCA insertion. These two Tech Specs are excerpted from the A. W. Vogtle Unit 1 Tech Specs and are provided in Appendix B. Tech Spec 3.1.3.5 precludes Shutdown RCCA insertion in Modes 1 and 2, and Tech Spec 3.1.3.6 limits Control Bank insertion via the Rod Insertion Limits (RILs). The RILs have been analysed assumming the limiting ARO RCCA Repositioning specification of 222 steps withdrawn.

Control rods can be inserted as a function of power level according to the RILs, and all RCCAs are inserted upon reactor trip. With greater RCCA insertion, MTC becomes more negative relative to the ARO MTC, all other parameters being held equal. However, Tech Specs do not allow all other parameters to be held equal. With deeper RCCA insertion, power must be reduced and Tavg will be reduced accordingly. The reduction in Tavg serves to make the MTC more positive, and at EOL 0 ppm conditions, this positive Tavg effect will entirely offset the negative RCCA effect on MTC.

For example, for Reload A, complete insertion of both control Banks D and C at EOL 0 ppm HFP conditions (a condition not permissible under normal operation) will make the MTC [$]^{+a,c}$ pcm/°F more negative than the ARO MTC. However, in going from a nominal HFP Tavg to a nominal HZP Tavg at EOL and 0 ppm, the MTC for this same core becomes [$]^{+a,c}$ pcm/°F more positive. This [$]^{+a,c}$ pcm/°F more positive component of the MTC that results from the moderator temperature (density) change in going from HFP to HZP will also more than compensate the negative MTC component that arises from total RCCA insertion with trip.

The Reload A core design is typical of reloads for Westinghouse-designed PWRs in this respect. Because the rate at which decreasing moderator temperature makes MTC positive exceeds the rate at which allowable RCCA insertion makes MTC negative, the most negative MTC situation will always exist at HFP Tavg with RCCAs inserted to the extent allowed by the HFP insertion limits. For this reason, the maximum RCCA deviation from nominal conditions allowable by the Tech Specs only needs to be assessed at the HFP condition.

Figure 3.2 shows the RCCA insertion limits for both A. W. Vogtle unit's reload cores. These correspond to the insertion limits for the Vogtle 4 loop core with the five control rod lead control bank of Figure 3.1. Figure 3.2 shows that at full power the lead control bank can be inserted to a depth of 161 steps withdrawn. However, strict application of these current RILs in determining the "delta MTC" factor associated with RCCA insertion may prove to be restrictive if minor changes to the RILs become necessary in the future. For this reason, the HFP RCCA insertion assumed for this analysis is [ ]$^{+a,c}$ steps withdrawn. This additional insertion is expected to bound minor RIL adjustment which may be necessary for optimizing core performance characteristics of future A. W. Vogtle reloads. [ ]$^{+a,c}$ therefore, a RIL adjustment to lead control bank insertion beyond [ ]$^{+a,c}$ steps withdrawn will not necessarily invalidate the revised EOL MTC LCO value.

This limiting HFP RCCA insertion of [ ]$^{+a,c}$ steps withdrawn forms the basis of the determination of MTC sensitivity to HFP RCCA insertion, which is described in Appendix A. The overall "delta MTC" factor associated with RCCA insertion is derived directly from this [ ]$^{+a,c}$ steps withdrawn lead control bank position, and was determined to be [ ]$^{+a,c}$ pcm/°F. This includes a component resulting from ARO RCCA repositioning specification in the range of 222-231 steps withdrawn.

Axial Flux (Power) Shape Deviation

As indicated earlier, MTC is affected by the axial flux shape which exists in the core, primarily as a result of the influence which the axial flux shape has on the rate at which the moderator is heated as it moves up the core. The detailed shape itself is not so important, but rather the "balance" of the flux shape, in terms of how much moderator heating occurs in the lower half of the core versus the upper half of the core. The influence which axial power shape has on MTC can, therefore, be captured by quantifying this axial flux "balance", and this balance is best quantified by the core's Axial Flux Difference (AFD).

The discussion of the MTC sensitivity to axial flux (power) shape presented in Appendix A establishes that the more negative the AFD becomes, the more negative the MTC will become. The axial flux (power) shape deviation is, therefore, determined by how negative the AFD is allowed to become under normal full power operating conditions.

The A. W. Vogtle units presently employ a target AFD band of +3% to -12% about a target value of AFD. Current and anticipated future A. W. Vogtle core designs produce target AFD values which are no more negative than [ ]$^{+a,c}$. This [ ]$^{+a,c}$ target AFD, combined with a bank allowance of -12% means that the most negative HFP AFD value for A. W. Vogtle reload cores allowed by Tech Specs would be [ ]$^{+a,c}$. To assign a "delta MTC" factor attributable to axial flux shape, one need only examine the MTC effect associated with a [ ]$^{+a,c}$ "deviation" from a "balanced" (i.e. 0% AFD) flux shape. [ ]$^{+a,c}$, an AFD value of [ ]$^{+a,c}$% is selected as the basis of the axial flux (power) shape deviation. This [ ]$^{+a,c}$% AFD deviation is applied to the MTC sensitivity to axial flux (power) shape, which is described in Appendix A, to obtain an overall "delta MTC" factor associated with AFD deviation from a perfectly balanced axial flux shape. The resulting "delta MTC" factor is [ ]$^{+a,c}$ pcm/°F.

Transient Fission Product (Xenon) Concentration Deviation

Xenon is the most significant transient fission product in terms of effects on core reactivity and flux distribution; therefore, its possible impacts on MTC are investigated to compute the final "delta MTC" factor to include in the Most Negative Feasible MTC approach. While Tech Specs place no limitations on either xenon distribution or overall concentration, the AFD limits discussed above, in effect, place a limitation on the amount of axial xenon skewing that can occur, and the physics of xenon buildup and decay place practical limits on the concentration. Because axial xenon distribution directly impacts axial flux shape, this aspect of xenon effect on MTC is implicitly included in the axial flux (power) shape deviation discussed above. What remains to be quantified is the impact of the overall xenon concentration in the core.

Taking the EOL HFP ARO equilibrium xenon concentration to be the nominal xenon condition for the core, it was determined for low leakage core designs of the type characteristic of A. W. Vogtle reloads, the MTC would become more negative with a reduced xenon concentration. Accordingly, the most negative MTC results when there is no xenon in the core.

It was established in the discussion on moderator temperature and pressure deviation and on RCCA insertion deviation, that the condition for the most negative MTC requires maximum allowable temperature (minimum allowable density) and, therefore, occurs at full power conditions. While the assumption of achieving full power operation with no xenon in the core is certainly a conservative assumption, the possibility of steady power escalation after an extended shutdown period presents a reasonable scenario for full power operation with a comparatively low xenon concentration in the core. For this reason, the "xenon deviation" to be used in conservatively determining the "delta MTC" factor attributable to transient fission product is a change from HFP ARO equilibrium xenon to no xenon in the core. The resulting "delta MTC" factor is [ ]$^{+a,c}$ pcm/°F.

3.4 Overall "Delta MTC" Factor for A. W. Vogtle Units 1 and 2 Reloads

The preceding section has concluded that the most adverse operation possible, in terms of achieving the most negative EOL MTC under current A. W. Vogtle Units 1 and 2 Tech Specs, would feature the following values of key parameters:

- Core Moderator Temperature: 7.2°F above HFP nominal
- Core Moderator Pressure: 2200 psia
- HFP RCCA insertion: [ ]$^{+a,c}$ steps withdrawn
- HFP most negative AO: [ ]$^{+a,c}$
- HFP xenon concentration: 0 %

When these maximum allowable deviations from a nominal condition of EOL HFP ARO, with equilibrium xenon, and 0 ppm boron are applied to the individual parameter sensitivities discussed in Appendix A, the overall "delta MTC" factor is computed. This overall factor for the A. W. Vogtle units was computed to be as follows:

- Core Moderator Temperature and Pressure Factor:	[ ]$^{+a,c}$ pcm/°F
- HFP RCCA Insertion Factor:	[ ]pcm/°F
- Axial Flux (Power) Shape Factor:	[ ]pcm/°F
- Xenon Concentration Factor:	[ ]pcm/°F
Overall "Delta MTC" Factor:	[ ]pcm/°F

The interpretation of this overall "delta MTC" factor is as follows. The Tech Spec LCO value of EOL MTC is based on the explicit conditions of unrodded full power operation. This is an appropriate condition for performing a MTC experiment and obtaining results that can be meaningfully compared to design predictions. It is not, however, the condition under which the MTC can achieve its most negative value under normal operation scenarios permitted by the Tech Specs. The conservative "delta MTC" formulation has concluded that the actual core MTC can be as much as [ ]$^{+a,c}$ pcm/°F more negative than the EOL MTC LCO value defined by the Tech Specs. The individual components of this [ ]$^{+a,c}$pcm/°F overall "delta MTC" factor have been determined on a

conservative basis and are expected to bound the values predicted for A. W. Vogtle reload cores in the future. While an individual component could conceivably exceed the value cited above, such an occurrance would not invalidate the Most Negative Feasible MTC approach, as long as the total of all the components remains bounded by the [ ]$^{+a,c}$pcm/°F overall "delta MTC factor. [ ]$^{+a,c}$.

3.5 Proposed A. W. Vogtle Units 1 and 2 Tech Spec EOL MTC LCO Value

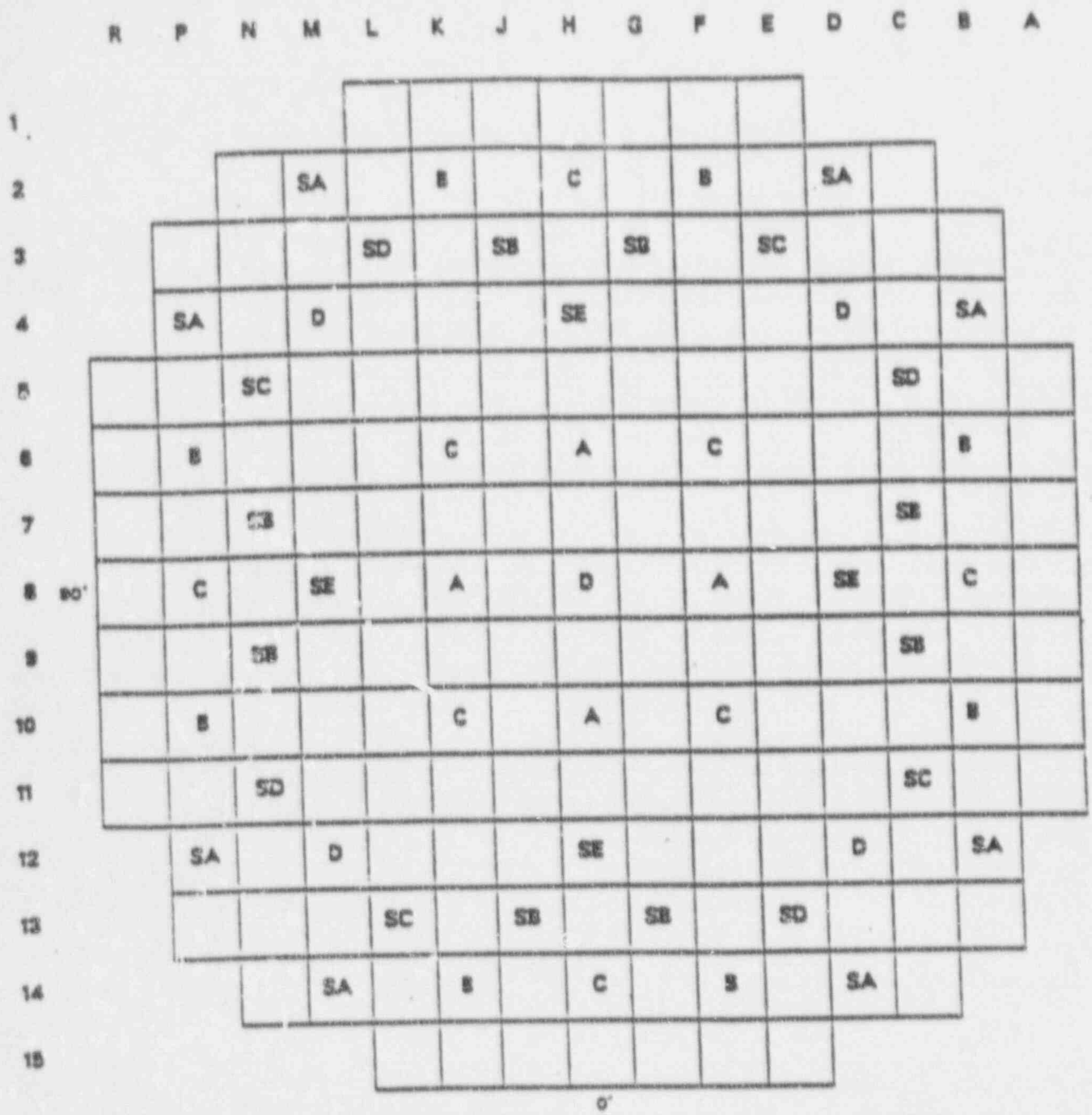
As was pointed out in Section 3.1, A. W. Vogtle FSAR accident analyses have assumed a MDC value which, when converted to a MTC at nominal HFP conditions, is equivalent to a MTC of -56 pcm/°F. At no time may the actual core be allowed to experience a MTC more negative than -56 pcm/°F, as this would invalidate an assumption of the accident analyses. The Most Negative Feasible MTC approach assures that such a situation will not occur by subtracting from this -56 pcm/°F MTC value the [ ]$^{+a,c}$ pcm/°F "delta MTC" factor determined for the A. W. Vogtle units. The resulting value, [ ]$^{+a,c}$pcm/°F, is proposed as the Tech Spec EOL LCO value of MTC under the Most Negative Feasible MTC approach. As an additional measure of conservatism, this value is further increased to -48 pcm/°F, and proposed as the EOL HFP ARO Tech Spec MTC LCO value for A. W. Vogtle reload cores, replacing the current LCO value of -40 pcm/°F.

The -48 pcm/°F proposed limit provides relief over the -40 pcm/°F limit associated with the current Tech Spec ARO-to-ARI conversion requirement, yet still represents a conservative formulation. The scenario of deep RCCA insertion, coupled with high Tavg, low system pressure, and no xenon, represents a compounding of worst case events which can be considered independent, yet are not treated as such in the Most Negative Feasible MTC formulation. Determination that the core MTC is less negative than -48 pcm/°F

at EOL HFP ARO conditions provides assurance that the assumption on initial condition MTC made in the plant accident analyses remains bounding. Additional assurance that the MTC (MDC) will not become more limiting at any time during a transient is also needed, in order to demonstrate that the accident analysis conclusions remain valid. This additional assurance is the primary subject of Section 4.0.

Figure 3.1

Vogtie Control Rod Locations

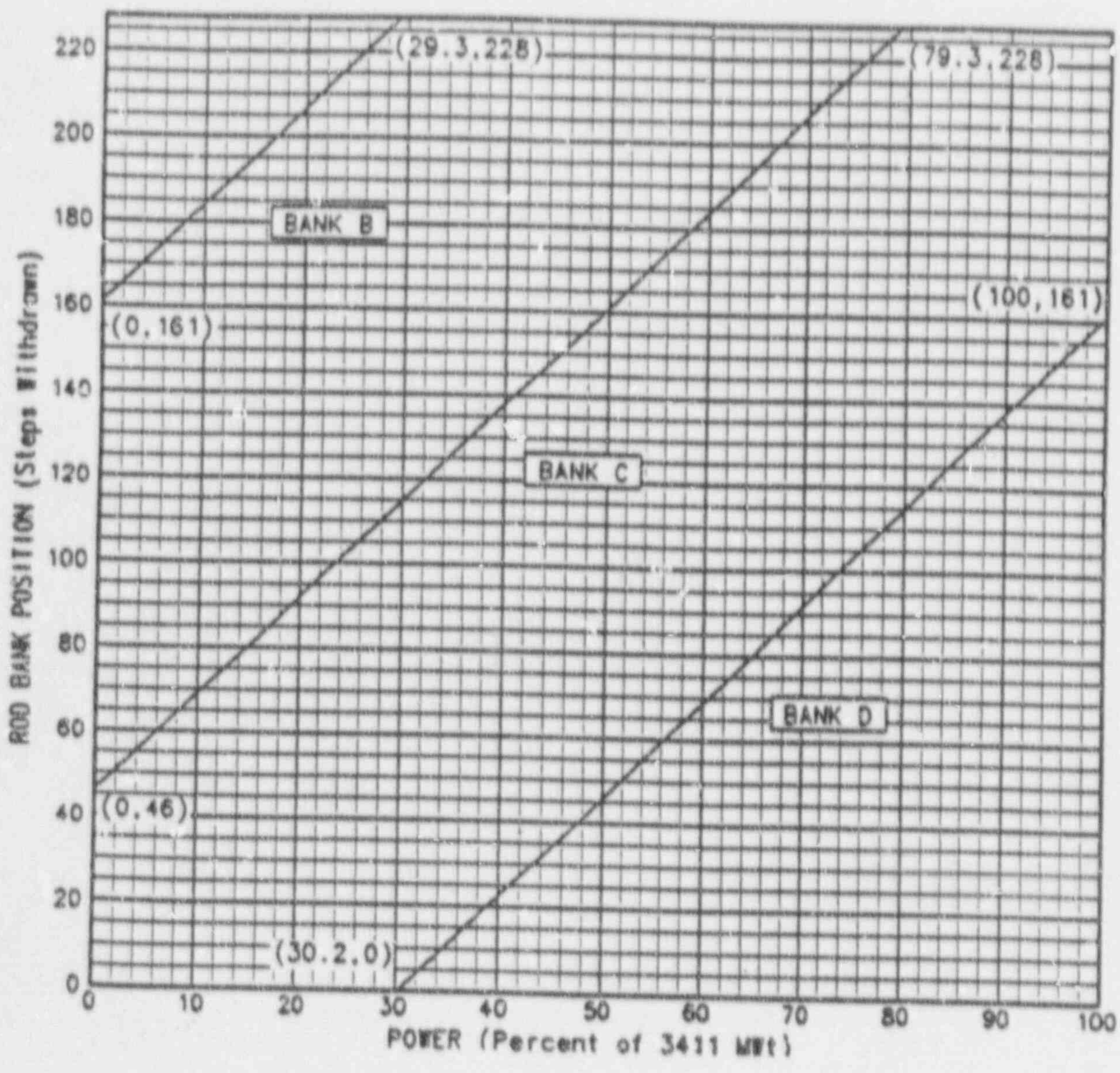


CONTROL BANKS	NUMBER OF CLUSTERS	SHUTDOWN BANKS	NUMBER OF CLUSTERS
D	5	SE	4
C	8	SD	4
B	8	SC	4
A	4	SB	8
		SA	8

Figure 3.2

RCCA Insertion Limits for
A. W. Vogtle Units 1 and 2 Reload Cores

(113 STEP OVERLAP)



4.0 SAFETY ANALYSIS IMPACT OF MOST NEGATIVE FEASIBLE MTC APPROACH

The accident analyses conservatively model the various reactivity coefficients to produce a bounding analysis. As discussed in Section 3.1, the applicable analyses assume a constant MDC of 0.43 Δk/gm/cc to bound the predicted moderator reactivity insertion. The events which assume this value for EOL MDC are listed in Table 4.1.

The Most Negative Feasible MTC approach determines the conditions for which a core will exhibit the most negative MTC value that is consistent with operation allowed by the Tech Specs. Thus, the value for the Most Negative Feasible MTC provides the basis for a conservative initial condition assumption.

Changes in the parameters identified in Section 2.3 could take place during a transient in such a way as to make the MTC more negative than that allowed under normal operation. However, the most adverse conditions seen in these events will not result in a reactivity insertion which would invalidate the conclusions of the FSAR accident analyses. Therefore, the 0.43 Δk/gm/cc assumption used as the basis for the Most Negative Feasible MTC Tech Spec will not change.

As discussed in Reference 6, the reactivity coefficients assumed can have a strong influence on accident analysis results. [ ]$^{+a,c}$ This process ensures the ability to verify that the applicable safety limits are met for each reload design and, consequently, that the Tech Specs are met.

TABLE 4.1

FSAR Chapter 15 Events Which Assume A Constant 0.43Δk/gm/cc Value of MDC

15.1.1	Feedwater System Malfunctions That Result in a Decrease in Feedwater Temperature
15.1.3	Excessive Increase in Secondary Steam Flow
15.2.2	Loss of External Electrical Load
15.2.3	Turbine Trip
15.4.2	Uncontrolled Rod Cluster Control Assembly Bank Withdrawal at Power
15.5.4	Startup of an Inactive Reactor Coolant Pumpt at an Incorrect Temperature

5.0 DETERMINATION OF MOST NEGATIVE FEASIBLE MTC SURVEILLANCE VALUE

Section 1.3 pointed out the potential conservatism in the separation of 9 pcm/°F between the Tech Spec 300 ppm MTC SR value and the EOL HFP ARO MTC LCO value. Typical 17x17 reload designs exhibit a predicted difference between the 300 ppm HFP design MTC and the EOL HFP ARO design MTC which is much less than 9 pcm/°F. However, in order to justify the use of a value which is smaller than 9 pcm/°F for a given plant, the specific design prediction history of the plant must be examined.

Preliminary calculations for the A. W. Vogtle reload cores were reviewed in order to determine the largest difference between the predicted 300 ppm HFP MTC and the predicted EOL HFP MTC. The magnitude of the difference shows little variation for reload cores analysed. The maximum difference determined was [ ]+a,c pcm/°F.

In reviewing the differences between predicted 300 ppm and EOL MTC values for the A. W. Vogtle reload cores, an important trend was discerned. It was observed that the higher core average enrichments associated with increasing discharge burnup tend to decrease the magnitude of MTC difference. Conversely, as the reloads transition to OFA fuel, the MTC difference will increase. [ ]+a,c

The proposed Tech Spec SR value for Vogtle reload cores is -40.5 pcm/°F. This value is 7.50 pcm/°F less negative than the EOL LCO MTC value proposed in Section 3.5. The 7.50 pcm/°F was chosen to conservatively [ ]+a,c afford relief from the 9 pcm/°F difference applied by the current Tech Specs. [ ]+a,c

6.0 SUSPENSION OF MTC MEASUREMENTS BELOW 100 PPM

As indicated earlier, major drawbacks of the EOL MTC surveillance measurements include the large volumes of water that must be processed (and accompanying large volume of waste water created) for measurements performed via the boration and dilution method, and the need to force the plant to deviate from nominal operation conditions in order to gather test data. These problems become particularly acute when core boron concentrations reach low values, as a result of the increased time needed to achieve the required dilution.

Keeping the reactor in a "perturbed" condition (i.e. power/program temperature mismatch) is never desirable, hence the low boron concentration MTC testing should not be performed unless absolutely necessary to demonstrate compliance with the Tech Spec EOL HFP MTC LCO value. This is the primary reason that acceptable results for the 300 ppm MTC surveillance preclude further testing. However, even if the 300 ppm MTC test result fails to satisfy the Tech Spec SR value, there is some question as to whether further testing should be performed for the remainder of the operating cycle in every case.

It is proposed that the HFP MTC testing requirement be suspended for equilibrium boron concentrations below 100 ppm if a secondary surveillance criteria on the MTC is satisfied by a HFP MTC measurement performed at or below 100 ppm. This secondary surveillance criteria value is -44 pcm/°F. This value is set, with due consideration for MTC behavior with boron concentration reduction and fuel depletion, to ensure that the proposed EOL (essentially 0 ppm) HFP ARO LCO value of -48 pcm/°F will be met, even if no further measurement is conducted.

Figure 6.1 shows the HFP equilibrium critical boron concentration and MTC behavior with burnup that is anticipated for Vogtle reload cores. Note that the 300 ppm MTC value shows sufficient margin to the proposed 300 ppm SR value of -40.5 pcm/°F that repeated MTC measurements are not expected to be necessary. However, should the 300 ppm MTC test result be more negative than the proposed SR value, examination of the MTC behavior with further cycle depletion becomes important. Figure 6.2 shows this same typical Vogtle MTC as a function of boron concentration, and also depicts a curve connecting the proposed 300 ppm SR value and the EOL (0 ppm) Tech Spec LCO value. Note that the slope of the "typical" MTC line is somewhat less steep than the line connecting the Tech Spec values. This more gradual change of actual MTC behavior with further core depletion indicates that failing to meet the 300 ppm SR value will not necessarily result in failure to meet the LCO limit.

The proposed secondary surveillance criteria value of -44 pcm/°F is plotted on Figure 6.2 at a boron concentration of 100 ppm. A line connecting the proposed 300 ppm SR value of -40.5 pcm/°F and the proposed secondary surveillance value has a slope which is more characteristic of actual MTC behavior. Projecting this line down to a boron concentration of 0 ppm shows that such MTC behavior assures margin to the EOL LCO limit of -48 pcm/°F.

Failure to meet the 300 ppm SR value requires that the MTC measurement be performed every 14 EFPD. This repeat measurement requirement would result in up to five MTC measurements being taken prior to reaching a 100 ppm equilibrium boron concentration. A final measurement performed at or below 100 ppm would serve to confirm that satisfying the LCO value is assured through satisfying the secondary surveillance value.

Satisfying the secondary surveillance provides exemption from only the two MTC measurements that would otherwise occur during the final month of full power operation. However, it is these last two measurements that would be most problematic to perform; therefore satisfying the secondary surveillance limit of -44 pcm/°F can preclude operation in a perturbed state at a time when such operation is least desirable.

Figure 6.1

HFP CRITICAL BORON CONCENTRATION AND MTC
VERSUS BURNUP FOR VOGTLE RELOAD

+a,c

Figure 6.2

HFP MTC VERSUS CRITICAL BORON CONCENTRATION
FOR VOGTLE RELOAD

+a,c

7.0 CONCLUSIONS

The present A. W. Vogtle unit's Technical Specification values of -40 pcm/°F for the EOL HFP ARO MTC LCO and -31 pcm/°F for the 300 ppm HFP ARO SR conservatively reflect the FSAR accident analysis MDC assumption, but are considered to be overly restrictive by potentially requiring repeated deviation from nominal plant operation. An alternative adjustment procedure is proposed which is based on a conservative determination of the extent to which a nominal EOL HFP ARO MTC value can be made more negative under the most extreme values of certain operational parameters that are permitted by other Tech Specs. This Most Negative Feasible MTC approach assumes that these largely independent extreme situations occur simultaneously, and in the worst case, serve to make the EOL HFP MTC [ ]$^{+a,c}$ pcm/°F more negative than it would be at nominal conditions. When this value is subtracted from the MTC equivalent of the accident analysis assumed MDC value, the resulting MTC is [ ]$^{+a,c}$ pcm/°F.

The slightly more conservative value of -48 pcm/°F is, therefore, proposed as the EOL HFP MTC Tech Spec LCO limit under the Most Negative Feasible MTC approach.

Examination of the differences between the 300 ppm HFP equilibrium boron concentration MTC value and the EOL HFP MTC values concluded that a typical expected difference between these two MTC values for A. W. Vogtle reload cores is -7.50 pcm/°F. This difference is subtracted from the proposed -48 pcm/°F EOL HFP MTC Tech Spec limit to arrive at a proposed Tech Spec 300 ppm HFP MTC SR value of -40.5 pcm/°F.

It is concluded that the Tech Spec EOL MTC LCO and 300 ppm SR values proposed under the Most Negative Feasible MTC approach do not impact conclusions of FSAR accident analyses, because they do not affect the accident analysis assumption on MDC. In addition, the validity of the above-stated LCO and SR MTC values, as well as the plant's ability to comply with them, [ ]$^{+a,c}$

Additional flexibility in the requirement for repeated EOL HFP MTC measurement is proposed by permitting exclusion from the repeat measurement requirement for HFP equilibrium boron concentrations below 100 ppm. Exclusion would be permitted if the first HFP MTC measurement taken after reaching 100 ppm HFP equilibrium boron concentration is less negative than -44 pcm/°F, as this provides assurance that the ultimate EOL (0 ppm) HFP ARO MTC value will not violate the LCO limit.

The new EOL MTC LCO and 300 ppm SR MTC values and the revised basis for adjustment overcome the problems inherent with the present version of Tech Spec 3/4.1.1.3, yet still afford protection. Tech Spec 3/4.1.1.3 continues to require that surveillance be performed, so that any deviations between the operating core and design predictions that might threaten the validity of accident analysis assumptions can be detected, and continued surveillance and appropriate action undertaken.

REFERENCES

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APPENDIX A

DETERMINATION OF MOST NEGATIVE FEASIBLE MTC SENSITIVITIES

Investigation of the sensitivity of MTC to core operational parameters that are variable under normal core operation is a fundamental requirement of the Most Negative Feasible MTC approach. Of the parameters discussed in Section 3.2, those that required detailed evaluation are:

- moderator temperature and pressure
- RCCA insertion
- axial flux (power) shape
- transient fission product (xenon) concentration

For each of these parameters, the sensitivity analyses were performed by perturbing the parameter in such a way as to induce a change from its nominal EOL value, and then performing a MTC determination with the parameter held in the perturbed stat . A further perturbation was induced and the MTC calculation repeated. This sequence was repeated until sufficient data was obtained to reliably determine the trend of MTC change with variation in the value of the parameter.

In order to establish trends in MTC that are appropriate and bounding for the reload core type of interest, the sensitivity calculations were performed for three different Vogtle reload cores. These cores exhibit a spectrum of design features (such as cycle length, fuel lattice design, etc.) that permit the MTC sensitivity results to have broad application for current and anticipated Vogtle reload cores. A brief description of the three Vogtle reload core designs follows:

RELOAD A: This core is the initial Vogtle Unit 1 reload core (Cycle 2). It utilizes the Westinghouse 17x17 fuel design and operates at a nominal core average moderator temperature of 591.8°F (3411 MWt). The cycle length is 427 effective full power days (EFPD). The reload uses a low leakage loading pattern fuel placement arrangement. The discharge region burnup is necessarily low, as it is the first reload. The control rod absorber material is hafnium.

The second Vogtle reload core (Cycle 3) incorporates the same fuel management, and core conditions. Sensitivity calculations were performed for this core, with similar results as cycle 2.

RELOAD B: This core is the conceptual first transition reload cycle for A. W. Vogtle Unit 1. It utilizes the Westinghouse 17x17 OFA fuel design and operates at uprated core conditions corresspoonding to 3565 MWt. The cycle length is 480 EFPD. The reload uses a low leakage loading pattern fuel placement arrangement. The anticipated region average discharge burnup of the feed fuel is approximately 45,000 MWD/MTU. This reload core design is representative of anticipated reload transition cores for both A. W. Vogtle units.

RELOAD C: This core is the second transition reload cycle for A. W. Vogtle Unit 1. It is comprised of nearly all Westinghouse OFA fuel and operates at uprated core conditions. The cycle length is 480 EFPD. The reload uses a low leakage loading pattern fuel placement arrangement. The discharge region average burnup is approximately 45,000 MWD/MTU.

As stated in Section 3.2, all of these core designs feature the control bank configuration that will be used in A. W. Vogtle reload cores, which is shown in Figure 3.1.

The core neutronic models of these three reload cores were derived using standard Westinghouse design procedures and computer methods. The ARK code, which evolved from the LEOPARD(2) and CINDER(3) codes, was used to perform the fast and thermal spectrum calculations and is the basis for all cross sections, depletion rates, and reactivity feedback models. ANC(4), a nodal analysis theory code that is used in two and three dimensions, was used for core neutronic calculations to determine MTC sensitivity for the three reload cores. APOLLO, an advanced version of PANDA(5), was used as an axial neutronic model of the reload cores to determine MTC sensitivity to varying axial flux shape.

The neutronic calculations performed for the Vogtle reload core designs established MTC sensitivities for each of the parameters listed above. The sections which follow provide details of the calculations performed and the MTC sensitivity results obtained.

A.1 MTC Sensitivity to Moderator Temperature and Pressure Variation

The decrease in moderator density which accompanies moderator heatup has the effect of reducing neutron moderation. With a low soluble boron concentration in the moderator, this results in a more negative moderator temperature coefficient. An increase in coolant temperature, keeping density constant, leads to a hardened neutron spectrum and results in an increase in resonance absorption in U238, Pu240, and other isotopes. The hardened spectrum also causes a decrease in the fission-to-capture ratio in U235 and Pu239. Both of these effects make the MTC more negative. In addition, the hardened neutron spectrum results in a larger fast-to-thermal flux ratio which increases the leakage of the core. Again, the effect of higher leakage is to make the MTC more negative.

Since water density changes more rapidly with increasing temperature, and because of the spectrum hardening effects mentioned above, the MTC becomes progressively more negative with increasing temperature. The sensitivity of MTC to increasing temperature was determined for each of the three reload cores by increasing core reference moderator temperature slightly above the nominal HFP value, while holding pressure constant at 2250 psia, and then performing a MTC calculation that induced small changes in core K-effective via changes in moderator temperature and density about the reference values. The effects of changes in moderator temperature and density were considered together. After the MTC value was computed, core reference moderator temperature was further increased, and another MTC calculation performed. This process was repeated until the trend of MTC with increasing core reference moderator temperature was clearly established.

Results were recorded for the Vogtle reload cores in terms of change in MTC from the nominal HFP MTC as a function of increase in reference moderator temperature above the nominal HFP moderator temperature. The results are shown in Figure A.1. [ ]$^{+a,c}$

To use the [ ]$^{+a,c}$ MTC sensitivity information of Figure A.1, the maximum allowable temperature and pressure (and, therefore, density) deviations permissible under operation that complies with Tech Specs must also be determined. These deviation values, presented in Section 3.3, are combined with the sensitivity data to arrive at a "delta MTC" factor associated with moderator temperature and pressure (and, therefore, density). For the 7.2°F temperature deviation cited in Section 3.3, Figure A.1 indicates that the corresponding "delta MTC" due to temperature increase is [ ]$^{+a,c}$pcm/°F.

The calculations which determined the MTC sensitivity to increasing moderator temperature were performed at a constant RCS presure of 2250 psia, and hence, do not reflect the effect of the 50 psi pressure deviation cited in Section 3.3. The moderator density perturbation caused by a pressure decrease of 50 psi was calculated, and the effect of this density change on MTC was determined. The "delta MTC" due to the moderator density change associated with the 50 psi pressure deviation was conservatively determined not to exceed [ ]$^{+a,c}$pcm/°F. The combined pressure and temperature "delta MTC" factor is, therefore, [ ]^{a,c}pcm/°F.

A.2 MTC Sensitivity to RCCA Insertion

With constant moderator temperature, pressure, and boron concentration, insertion of control rods makes MTC more negative. This trend in MTC arises from three effects. The first is that RCCA insertion makes the overall flux spectrum slightly harder, which makes MTC more negative, as discussed in Section A.1.

The second effect is that RCCA insertion will increase core leakage, which again makes MTC more negative. The third effect arises from the impact of RCCA insertion on axial flux (power) shape, and this effect is treated separately in Section A.3.

Control rods can be inserted as a function of power level according to the RCCA insertion limits (RILs), and all RCCAs are inserted upon reactor trip. With greater RCCA insertion, MTC becomes more negative relative to the ARO MTC, all other parameters being held equal. However, Tech Specs do not allow all other parameters to be held equal. With deeper RCCA insertion, power must be reduced and Tavg will be reduced accordingly. The reduction in Tavg serves to make the MTC more positive, and at EOL 0 ppm conditions, this positive Tavg effect will entirely offset the negative RCCA effect on MTC. The overall result is that the most negative MTC that can exist in the core occurs at HFP; therefore, the MTC sensitivity to RCCA insertion need only be determined at HFP conditions for HFP allowed RCCA insertion. The sensitivity will also account for anticipated changes in the ARO RCCA specification to 222 steps withdrawn.

To calculate the EOL HFP MTC sensitivity to RCCA insertion, each of the Vogtle reload core models had the lead control bank inserted the maximum applicable amount determined from Section 3.3 ([$]^{+a,c}$ steps withdrawn), at HFP, with no soluble boron in the core. The MTC value for this condition was then determined by inducing small changes in core K-effective via changes in moderator temperature and density about their reference values. This MTC value was compared to the MTC determined at the same conditions, but with all RCCAs removed from the core.

Of the reload cores analyzed, it was determined that the maximum change to the EOL 0 ppm HFP ARO MTC which occurred as a result of HFP RCCA insertion to a depth of [$]^{+a,c}$ steps withdrawn was [$]^{+a,c}$ pcm/°F. Because this change to MTC arising from RCCA insertion was determined at HFP equilibrium conditions, it is appropriate to factor in any further effect on MTC that may arise from increasing RCCA worth, at a fixed insertion, as a result of an

expected operational transient. It was determined that the MTC would be made, at most, [ ]+a,c pcm/°F more negative as a result of HFP RCCA worth being "enhanced" by transient operation, therefore, the [ ]+a,c "delta MTC" factor associated with allowable HFP RCCA insertion becomes [ ]+a,c pcm/°F.

A.3 Sensitivity to Axial Flux (Power) Shape

MTC is not so much directly affected by axial flux distribution itself, but is affected via the impact which the axial flux distribution has on the rate at which the moderator is heated as it moves up the core, and via the importance weighting which the axial flux shape imparts to different regions of the core.

In general, the accumulated burnup in the bottom half of the core exceeds that in the top half of the core, as indicated in Figure A.2 for EOL of Reload C. Other things being equal, higher burnup results in a more negative MTC as a result of isotopic impacts on flux spectrum. A more negative axial flux (power) shape allocates a greater "importance weighting" to the lower regions of the core where burnups are greater, thereby accentuating this effect.

A greater effect is the impact which axial flux (power) shape has on heating rate of the moderator as a function of axial elevation. Figure A.3 shows, in the top diagram, three distinct axial power shapes - one which is skewed toward the bottom of the core, one which is skewed toward the top of the core, and one which is balanced, with an axial offset near zero. The lower diagram in Figure A.3 shows the core moderator temperature as a function of core height for these three different axial power distributions. While the same temperature rise through the core occurs for all three power shapes, it is evident that a more bottom-skewed axial power distribution will give rise to a higher average moderator temperature. This results from the greater heating of the moderator in the lower core elevations for the bottom-skewed case. As energy is added to the moderator at higher elevations, the temperature still remains highest for the bottom-skewed power case because of its initial "head start" in the lower elevations. The temperature differences gradually decrease as a result of the differing heating rates occurring in the upper core regions among the three shapes.

Both the importance weighting effect and the moderator axial heating rate effect indicate that a more bottom-skewed flux shape (more negative Axial Flux rence) will result in a more negative MTC. This effect was investigated for the three reload cores at EOL HFP 0 ppm conditions with no xenon in the core (xenon was removed so as to not complicate flux skewing strategy). A specific axial flux shape was induced and then, holding this flux shape approximately constant, the MTC was determined by observing the small changes in core K-effective which resulted from variation in moderator temperature and density about their reference values. A different axial flux shape was induced, and the MTC calculation repeated. This process was repeated until the behavior of MTC with variation in axial flux shape (as quantified by Axial Flux Difference) was clearly identified.

Curves of "delta MTC" as a function of Axial Flux Difference (AFD) for the three reload cores are shown in Figure A.4. Note that a zero AFD is taken as the reference point, therefore, "delta MTC" is fixed at zero for an AFD of zero. Because more negative AFD values result from RCCA insertion, this axial flux shape MTC sensitivity implicitly captures part of the RCCA MTC sensitivity not included in the "delta MTC" factor of the previous section.

Section 3.3 concludes that a negative value of HFP AFD [ ]$^{+a,c}$. Using the most conservative trend of Figure A.4 (that of Reload A) the "delta MTC" factor corresponding to [ ]$^{+a,c}$% AFD is [ ]$^{+a,c}$pcm/°F.

Figure A.3 indicates that for a markedly negative AFD, the core average moderator temperature could be as much as [ ]$^{+a,c}$°F higher than that seen for a core with a balanced axial power shape (AFD near 0). Recalling the MTC sensitivity to moderator temperature of Figure A.1, one would expect a much greater MTC sensitivity to AFD than is indicated by Figure A.4. While the volume-weighted moderator temperature for a very negative AFD may increase significantly above that of the balanced flux shape case, the power-weighted moderator temperature increase will be very modest, and this will result in rather weak MTC sensitivity to AFD.

To further illustrate this point, examination of Figure A.3 shows that the very negative AFD power shape imparts a significant "importance weighting" to the bottom portion of the core where moderator temperature is lowest, but in the top portion of the core, where moderator temperature is greatest, the relative importance weighting is low. This power "importance weighting" aspect serves to negate a great deal of the "volume-weighted" temperature effect described above, and makes the "effective" moderator temperature increase for very bottom-skewed power shape rather small. Again, this causes the MTC sensitivity to extremes of flux (power) shape to be rather weak.

A.4 Sensitivity to Transient Fission Product (Xenon) Concentration

Xenon is the most significant transient fission product in terms of effects on core reactivity and flux distribution, therefore, its possible impacts on MTC were investigated to compute the final "delta MTC" factor to include in the Most Negative Feasible MTC approach. While Tech Specs place no limitations on either xenon distribution or overall concentration, the AFD limits discussed in Section 3.3, in effect, place a limitation on the amount of axial xenon skewing that can occur, and the physics of xenon buildup and decay place practical limits on the concentration. The effects of other fission products, namely Samarium, were not investigated. Their effect on MTC is considered negligible due to the large decay times (in comparison to the affected transient events) of precursor fission products, and also, the relatively lower concentrations that result.

Because axial xenon distribution directly impacts axial flux shape, this aspect of xenon effect on MTC is implicitly included in the Axial Flux Shape "delta MTC" factor discussed in Section A.3. What remains to be determined is the sensitivity to overall xenon concentration in the core. Calculations to determine this sensitivity were performed with the ANC[4] code, taking the EOL HFP ARO 0 ppm MTC value with an equilibrium concentration of xenon as the reference value of MTC. A number of differing xenon concentration scenarios were modeled, and the MTC value associated with each scenario was determined.

For all Vogtle three reload cores, the most negative MTC resulted when all xenon was removed from the core. The largest "delta" from the reference (equilibrium xenon) MTC that occurred when all xenon was removed was [ ]$^{+a,c}$pcm/°F. This value becomes the final "delta MTC" factor attributable to xenon. No further uncertainty is added, simply because the scenario of operating at full power with no xenon in the core is itself sufficiently conservative as to be bounding.

FIGURE A.1

CHANGE IN MTC WITH INCREASE IN T-AVERAGE
ABOVE NOMINAL T-AVERAGE

+a,c

FIGURE A.2

CORE AVERAGE AXIAL BURNUP VERSUS CORE HEIGHT AT EOL

+a,c

[ ]

FIGURE A.3

AXIAL POWER AND MODERATOR TEMPERATURE VERSUS CORE HEIGHT

+a,c

[ ]

+a,c

[ ]

FIGURE A.4

DELTA MTC VERSUS AXIAL FLUX DIFFERENCE AT EOL, HFP, ARO

+a,c

APPENDIX B

REFERENCED TECHNICAL SPECIFICATIONS AND BASES SECTIONS FROM THE A. W. VOGTLE NUCLEAR PLANT TECHNICAL SPECIFICATIONS

3/4.1.1 BORATION CONTROL

3/4.1.1.1 and 3/4.1.1.2 SHUTDOWN MARGIN

A sufficient SHUTDOWN MARGIN ensures that: (1) the reactor can be made subcritical from all operating conditions, (2) the reactivity transients associated with postulated accident conditions are controllable within acceptable limits, and (3) the reactor will be maintained sufficiently subcritical to preclude total loss of SHUTDOWN MARGIN in the shutdown condition.

SHUTDOWN MARGIN requirements vary throughout core life as a function of fuel depletion, RCS boron concentration, and RCS T_{avg}. In MODES 1 and 2, the most restrictive condition occurs at EOL, with T_{avg} at no load operating temperature, and is associated with a postulated steam line break accident and resulting uncontrolled RCS cooldown. In the analysis of this accident, a minimum SHUTDOWN MARGIN of 1.3% $\Delta k/k$ is required to control the reactivity transient. Accordingly, the SHUTDOWN MARGIN requirement is based upon this limiting condiion and is consistent with FSAR safety analysis assumptions. In MODES 3, 4 and 5, the most restrictive condition occurs at BOL, associated with a boron dilution accident. In the analysis of this accident, a minimum SHUTDOWN MARGIN as defined in Specification 3/4.1.1.2 is required to allow the operator 15 minutes from the initiation of the Source Range High Flux at Shutdown Alarm to total loss of SHUTDOWN MARGIN. Accordingly, the SHUTDOWN MARGIN requirement is based upon this limiting requirement and is consistent with the FSAR accident analysis assumptions. The required SHUTDOWN MARGIN is plotted as a function of RCS boron concentration.

3/4.1.1.3 MODERATOR TEMPERATURE COEFFICIENT

The limitations on moderator temperature coefficient (MTC) are provided to ensure that the value of this coefficient remains within the limiting condition assumed in the FSAR accident and transient analyses.

The MTC values of this specification are applicable to a specific set of plant conditions; accordingly, verification of MTC values at conditions other than those explicitly stated will require extrapolation to those conditions in order to permit an accurate comparison.

The most negative MTC, value equivalent to the most positive moderator density coefficient (MDC), was obtained by incrementally correcting the MDC used in the FSAR analyses to nominal operating conditions. These corrections

MODERATOR TEMPERATURE COEFFICIENT (Continued)

involved subtracting the incremental change in the MDC associated with a core condition of all rods inserted (most positive MDC) to an all rods withdrawn condition and, a conversion for the rate of change of moderator density with temperature at RATED THERMAL POWER conditions. This value of the MDC was then transformed into the limiting MTC value -4.0×10^{-4} $\Delta k/k/^{\circ}F$. The MTC value of -3.1×10^{-4} $\Delta k/k/^{\circ}F$ represents a conservative value (with corrections for burnup and soluble boron) at a core condition of 300 ppm equilibrium boron concentration and is obtained by making these corrections to the limiting MTC value of -4.0×10^{-4} $\Delta k/k/^{\circ}F$.

The Surveillance Requirements for measurement of the MTC at the beginning and near the end of the fuel cycle are adequate to confirm that the MTC remains within its limits since this coefficient changes slowly due principally to the reduction in RCS boron concentration associated with fuel burnup.

3/4.1.1.4 MINIMUM TEMPERATURE FOR CRITICALITY

This specification ensures that the reactor will not be made critical with the Reactor Coolant System average temperature less than 551°F. This limitation is required to ensure: (1) the moderator temperature coefficient is within its analyzed temperature range, (2) the trip instrumentation is within its normal operating range, (3) the pressurizer is capable of being in an OPERABLE status with a steam bubble, and (4) the reactor vessel is above its minimum RT_{NDT} temperature.

3/4.1.2 BORATION SYSTEMS

The Boron Injection System ensures that negative reactivity control is available during each mode of facility operation. The components required to perform this function include: (1) borated water sources, (2) charging pumps, (3) separate flow paths, and (4) the boric acid transfer pumps.

With the RCS average temperature above 200°F, a minimum of two boron injection flow paths are required to ensure functional capability in the event an assumed single failure renders one of the flow paths inoperable. The boration capability of either flow path is sufficient to provide a SHUTDOWN

LIMITING CONDITION FOR OPERATION

3.1.1.3 The moderator temperature coefficient (MTC) shall be:

a. Unit 1:

Less positive than $+0.7 \times 10^{-4}$ $\Delta k/k/^{\circ}F$ for the all rods withdrawn, beginning of cycle life (BOL), condition for power levels up to 70% RATED THERMAL POWER with a linear ramp to 0 $\Delta k/k/^{\circ}F$ at 100% RATED THERMAL POWER; and

Unit 2:

Less positive than 0 $\Delta k/k/^{\circ}F$ for the all rods withdrawn, beginning of cycle life (BOL), hot zero THERMAL POWER condition; and

b. Less negative than -4.0×10^{-4} $\Delta k/k/^{\circ}F$ for the all rods withdrawn, end of cycle life (EOL), RATED THERMAL POWER condition.

APPLICABILITY: Specification 3.1.1.3a. - MODES 1 and 2* only.**
Specification 3.1.1.3b. - MODES 1, 2, and 3 only.**

ACTION:

a. With the MTC more positive than the limit of Specification 3.1.1.3a. above, operation in MODES 1 and 2 may proceed provided:

1. Control rod withdrawal limits are established and maintained sufficient to restore the MTC to within the above limit within 24 hours or be in HOT STANDBY within the next 6 hours. These withdrawal limits shall be in addition to the insertion limits of Specification 3.1.3.6;

2. The control rods are maintained within the withdrawal limits established above until a subsequent calculation verifies that the MTC has been restored to within its limit for the all rods withdrawn condition; and

*With K_{eff} greater than or equal to 1.

**See Special Test Exceptions Specification 3.10.3.

3. A Special Report is prepared and submitted to the Commission, pursuant to Specification 6.8.2, within 10 days, describing the value of the measured MTC, the interim control rod withdrawal limits, and the predicted average core burnup necessary for restoring the positive MTC to within its limit for the all rods withdrawn condition.

b. With the MTC more negative than the limit of Specification 3.1.1.3b. above, be in HOT SHUTDOWN within 12 hours.

4.1.1.3 The MTC shall be determined to be within its limits during each fuel cycle as follows:

a. The MTC shall be measured and compared to the BOL limit of Specification 3.1.1.3a., above, prior to initial operation above 5% of RATED THERMAL POWER, after each fuel loading; and

b. The MTC shall be measured at any THERMAL POWER and compared to -3.1×10^{-4} $\Delta k/k/°F$ (all rods withdrawn, RATED THERMAL POWER condition) within 7 EFPD after reaching an equilibrium boron concentration of 300 ppm. In the event this comparison indicates the MTC is more negative than -3.1×10^{-4} $\Delta k/k/°F$, the MTC shall be remeasured, and compared to the EOL MTC limit of Specification 3.1.1.3b., at least once per 14 EFPD during the remainder of the fuel cycle.

SHUTDOWN ROD INSERTION LIMIT

LIMITING CONDITION FOR OPERATION

3.1.3.5 All shutdown rods shall be fully withdrawn.

APPLICABILITY: MODES 1* and 2,* #

ACTION:

With a maximum of one shutdown rod not fully withdrawn, except for surveillance testing pursuant to Specification 4.1.3.1.2, within 1 hour either:

a. Fully withdraw the rod, or

b. Declare the rod to be inoperable and apply Specification 3.1.3.1.

SURVEILLANCE REQUIREMENTS

4.1.3.5 Each shutdown rod shall be determined to be fully withdrawn:

a. Within 15 minutes prior to withdrawal of any rods in Control Bank A, B, C, or D during an approach to reactor criticality, and

b. At least once per 12 hours thereafter.

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*See Special Test Exceptions Specifications 3.10.2 and 3.10.3.

#With K_{eff} greater than or equal to 1.

CONTROL ROD INSERTION LIMITS

LIMITING CONDITION FOR OPERATION

3.1.3.6 The control banks shall be limited in physical insertion as shown in Figure 3.1-3.

APPLICABILITY: MODES 1* and 2* #.

ACTION:

With the control banks inserted beyond the above insertion limits, except for surveillance testing pursuant to Specification 4.1.3.1.2:

a. Restore the control banks to within the limits within 2 hours, or

b. Reduce THERMAL POWER within 2 hours to less than or equal to that fraction of RATED THERMAL POWER which is allowed by the bank position using the above figure, or

c. Be in at least HOT STANDBY within 6 hours.

SURVEILLANCE REQUIREMENTS

4.1.3.6 The position of each control bank shall be determined to be within the insertion limits at least once per 12 hours except during time intervals when the rod insertion limit monitor is inoperable, then verify the individual rod positions at least once per 4 hours.

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*See Special Test Exceptions Specifications 3.10.2 and 3.10.3.

#With K_{eff} greater than or equal to 1.

3/4.2.5 DNB PARAMETERS

LIMITING CONDITION FOR OPERATION

3.2.5 The following DNB-related parameters shall be maintained within the limits:

a. Reactor Coolant System T_{avg} (TI-0412, TI-0422, TI-0432, TI-0442), $\leq$ 591°F

b. Pressurizer Pressure (PI-0455A,B&C, PI-0456 & PI-0456A, PI-0457 & PI-0457A, PI-0458 & PI-0458A), $\geq$ 2224 psig*

c. Reactor Coolant System Flow (FI-0414, FI-0415, FI-0416, FI-0424, FI-0425, FI-0426, FI-0434, FI-0435, FI-0436, FI-0444, FI-0445, FI-0446) $\geq$396,198 gpm **

APPLICABILITY: MODE 1.

ACTION:

With any of the above parameters exceeding its limit, restore the parameter to within its limit within 2 hours or reduce THERMAL POWER to less than 5% of RATED THERMAL POWER within the next 4 hours.

SURVEILLANCE REQUIREMENTS

4.2.5.1 Reactor Coolant System T_{avg} and Pressurizer Pressure shall be verified to be within their limits at least once per 12 hours. RCS flow rate shall be monitored for degradation at least once per 12 hours. In the event of flow degradation, RCS flow rate shall be determined by precision heat balance within 7 days of detection of flow degradation.

4.2.5.2 The RCS flow rate indicators shall be subjected to CHANNEL CALIBRATION at each fuel loading and at least once per 18 months.

4.2.5.3 After each fuel loading, the RCS flow rate shall be determined by precision heat balance prior to operation above 75% RATED THERMAL POWER. The RCS flow rate shall also be determined by precision heat balance at least once per 18 months. Within 7 days prior to performing the precision heat balance flow measurement, the instrumentation used for performing the precision heat balance shall be calibrated. The provisions of 4.0.4 are not applicable for performing the precision heat balance flow measurement.

*Limit not applicable during either a THERMAL POWER ramp in excess of 5% of RATED THERMAL POWER per minute or a THERMAL POWER step in excess of 10% of RATED THERMAL POWER.

**Includes a 3.5% flow measurement uncertainty.

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