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3.4.0 Analysis of Technical Specifications – Unit 4

Learning Objectives:

1. Explain the significance of limiting conditions for operation in the areas of applicability, reactivity control systems, instrumentation, the reactor coolant system, and the emergency core cooling systems.
2. When given an initial set of operating conditions, use the format and content of the technical specifications to identify the applicable section from which to determine the appropriate plant and/or operator response.

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3.4.1 Introduction

This section is the last of the technical specification sections. It presents the limiting conditions for operation (LCOs) in the area of power distribution limits. Included are limits on:

- Heat flux hot channel factor (F_Q),
- Nuclear enthalpy rise hot channel factor ($F^N_{\Delta H}$),
- AXIAL FLUX DIFFERENCE (AFD), and
- QUADRANT POWER TILT RATIO (QPTR).

The definitions of these terms, their specified limits, and their bases are discussed in this section.

The heat flux hot channel factor and the nuclear enthalpy rise hot channel factor are peaking factors used to characterize core power distribution in terms of ratios of local maximum power output to average core output. These ratios are not monitored constantly; to ensure that they are maintained within limits between periodic measurements, limits are placed on gross measures of power distribution. The AXIAL FLUX DIFFERENCE provides a gross measure of axial power distribution, and the QUADRANT POWER TILT ratio provides a quadrant-to-quadrant comparison of core power generation. AFD and QPTR are constantly monitored; compliance with their limiting values provides assurance that the more infrequently measured peaking factors are maintained within limits.

The power distribution limits can vary with the core fuel cycle, in accordance with variations in the fuel loading characteristics. Traditionally, utilities have submitted technical specification amendments in order to change the limiting values for power distribution with new fuel loadings. In recent years most utilities have developed Core Operating Limits Reports (COLRs), which contain the limiting values for power distribution. For a plant which maintains a COLR, its power distribution LCOs contain the associated action statements and surveillance requirements but reference the COLR for the limiting values. In accordance with the requirements for the COLR in the administrative controls section of the technical specifications, the COLR is revised and submitted to the NRC without the need for technical specification amendments.

For consistency with the majority of nuclear plant technical specifications, the TTC Unit 2 technical specifications used in this course refer to the COLR for power distribution limiting values. The TTC Unit 2 COLR is referenced for plant-specific information in this section of the manual.

3.4.2 Core Thermal Limits

Power generation in the fuel and heat removal from the fuel assemblies are regulated so that fuel and cladding damage is avoided. Overheating of the fuel is prevented by maintaining the local peak linear heat generation rate below the level at which fuel centerline melting occurs. Overheating of the cladding is prevented by restricting all areas of the core to the nucleate boiling regime (i.e., by preventing a departure from nucleate boiling [DNB]).

Fuel centerline melting (the nominal melting point of uranium dioxide fuel is 5080°F) would cause expansion of the fuel pellet. The adjacent cladding could be stressed to the point of failure, allowing the uncontrolled release of fission product activity to the reactor coolant.

Operation beyond the nucleate boiling regime would result in excessive cladding temperatures because of the degradation in heat transfer between the clad and the reactor coolant that accompanies DNB. With the breakdown of nucleate boiling, steam films develop adjacent to the cladding, hindering heat transfer to the coolant and causing cladding temperatures to rise sharply. High cladding temperatures promote the zirconium/water reaction, which can weaken the cladding structural integrity to the point that the clad fails, again resulting in the uncontrolled release of activity to the reactor coolant.

The prevention of DNB is assured by operating the core with a departure from nucleate boiling ratio (DNBR) greater than the design limit. Recall that the DNBR is the ratio of the heat flux predicted to cause DNB to the actual local heat flux. The DNBR limit is statistically determined so that there is a 95% confidence level that 95% of the most limiting fuel rods do not experience DNB when the minimum local DNBR is at the DNBR limit (the classic “95/95” criterion). A DNBR limit of 1.3, as determined through the application of the Westinghouse W-3 correlation, has been applied to many Westinghouse cores. The applications of more recently developed correlations have resulted in DNBR limits as low as 1.13 or 1.17. The DNB correlations do not always conservatively predict DNB; to provide the desired assurance that DNB will not occur, a DNBR limit greater than 1.0 must be selected.

The prevention of fuel centerline melting and the maintenance of the DNBR above the design limit are assured during normal operation and anticipated operational occurrences (Condition I and II events) through compliance with the core safety limits (see Section 3.1 of this manual). Recall that the core safety limits are combinations of operational parameters: pressurizer pressure, the highest coolant loop average temperature (T_{avg}), and core thermal power (see technical specification Figure 2.1.1-1). These are all factors which affect DNBR; an increase in T_{avg}, a decrease in pressure, or an increase in local power density can cause the local heat transfer regime to approach DNB and thus decrease the DNBR. (A reduction in reactor coolant flow can also reduce the DNBR; the core safety limit curves assume the forced reactor coolant flow associated with four-loop operation.)

The power distribution LCOs support compliance with the core safety limits by maintaining local core conditions within design limits. In fact, the bases for the core safety limits state that the safety limit curves are based on the nuclear enthalpy rise hot channel factor limits provided in the COLR. In addition, the power distribution LCOs establish bounds on the initial conditions assumed in accident analyses.

3.4.3 Peaking Factors

Power plant operators have no direct indications of DNBR and fuel temperature. Local variations in fuel rod power are not measured by the instrumentation normally on line during power operation. To provide the operator with local power density information, the incore instrumentation system is used to construct flux maps of the core. The information from flux maps enables the calculation of peaking factors, which express core power distribution in terms of peak-to-average ratios. The two Westinghouse peaking factors which are periodically measured are the heat flux hot channel factor ($F_Q(Z)$) and the nuclear enthalpy rise hot channel factor ($F_{\Delta H}^{N}$). LCOs for these peaking factors are included in the technical specifications, and their limits are included in the COLR.

As stated in the technical specification bases, the peaking factor LCOs (and the associated limits in the COLR) establish limits on the power density at any point in the core so that the fuel design criteria are not exceeded and that the accident analysis assumptions remain valid. Control of the power distribution with respect to these factors ensures that local conditions in the fuel rods and coolant channels do not challenge core integrity at any location during either normal operation or a postulated accident analyzed in the safety analyses. The limits on $F_Q(Z)$and $F_{\Delta H}^{N}$ preclude core power distributions that exceed the following fuel design limits:

- There must be at least 95% probability at the 95% confidence level (the 95/95 DNB criterion) that the hottest fuel rod in the core does not experience a DNB condition (during both normal operation and a loss of flow accident);
- During a large-break loss of coolant accident (LOCA), the peak fuel clad temperature will not exceed the 2200°F limit specified by 10CFR50.46 as an acceptance criterion for emergency core cooling systems (ECCSs); During an ejected rod accident, the energy deposition to the fuel must not exceed 280 cal/gm; and
- The control rods must be capable of shutting down the reactor with a minimum required SHUTDOWN MARGIN with the highest worth control rod stuck fully withdrawn.

The bases for the peaking factor LCOs illustrate that the peaking factor limits provide a power distribution envelope for normal operation and establish the most extreme allowable power distribution at the start of an accident.

$F_Q(Z)$ and $F_{\Delta H}^{N}$ are discussed in detail in the following subsections.

3.4.3.1 Heat Flux Hot Channel Factor

F_Q is defined as the ratio of the maximum local fuel rod linear power density to the core average fuel rod linear power density. The limits for $F_Q(Z)$ have traditionally been expressed in the following form:

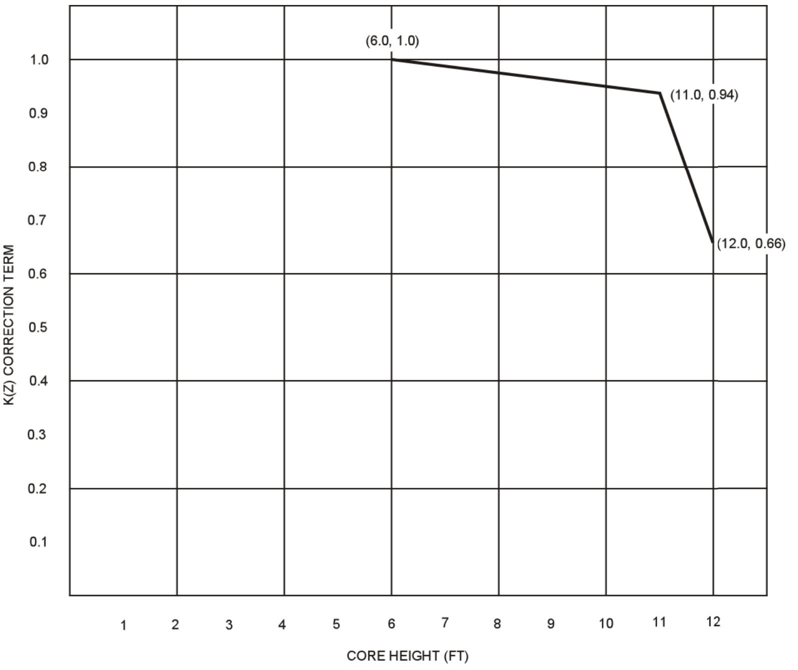
$$F_Q(Z) \le \frac{CFQ}{P} K(Z) \quad for \quad P > 0.5$$

$$F_Q(Z) \le \frac{CFQ}{0.5} K(Z) \quad for \quad P \le 0.5$$

Where: CFQ = 2.50

K(Z) is provided in Figure COLR-3, and

$P = \frac{thermal\ power}{rated\ thermal\ power}$, and



The above equations show that the $F_Q(Z)$ limits increase with decreasing thermal power. The average core linear power density is proportional to power, so at lower power levels the peak-to-average ratio of power density can be increased while the peak local linear power density is still maintained at a value which does not violate core design limits.

Also, the $F_Q(Z)$ limits include a height-dependent term. The function of core height is applied to ensure that the conditions in the core immediately prior to a LOCA are sufficiently limited that the 2200°F clad temperature limit is not exceeded during the accident. The K(Z) term is governed by the dynamics of core uncovery and reflood during LOCAs. During any

LOCA, the upper portion of the core blows down first and refloods last. The upper portion of the core thus stays uncovered longer than the lower portion. Imposing more restrictive $F_Q(Z)$ limits for approximately the upper half of the core limits the power density there at the start of an accident and the resulting increase in clad temperatures. Additionally, during certain small-break LOCAs the backpressure opposing reflood flow could result in the exceptionally slow reflooding of the very top of the core (the last one or two feet). The even more restrictive $F_Q(Z)$ limits for the very top of the core limit the clad temperatures that could be reached there during such a small-break LOCA.

Verification that $F_Q(Z)$ is within the specified limits is performed in accordance with one of two methodologies, known as the F_{xy} methodology and the F_Q methodology. The F_Q methodology is more widely used at Westinghouse plants today and is applied to the $F_Q(Z)$ LCO in the TTC Unit 2 technical specifications. Each methodology is briefly described in the following paragraphs.

3.4.3.1.1 F_{xy} Methodology

In accordance with the F_{xy} methodology, two surveillances are performed periodically to ensure that the measured values of F_Q are within the limits specified in the COLR. In the first surveillance, measured values of $F_Q(Z)$ (designated as F_Q^M) are determined from a steady-state flux map and increased by 3% to account for fuel manufacturing tolerances and by 5% for flux map measurement uncertainty (resulting in an effective multiplier of 1.0815 on each F_Q^M). These adjusted measured values (designated as F_Q^C) are compared to the limits (a function of core elevation because of the K(Z) term) for the power level at which the flux map is generated. The surveillance is satisfied if F_Q^C is less than the F_Q limit at each core elevation.

Because flux maps are generated at steady-state conditions, axial variations in power distribution for normal maneuvers such as load following are not present in the flux map data. It is important, therefore, that flux maps verify that radial peaking is limited during steady-state operation, so that highly peaked local power densities do not result from large changes in the axial power distribution that could accompany operational maneuvers. Accordingly, the F_{xy} methodology includes a second surveillance which verifies that radial peaking is within limits. $F_Q(Z)$ can be expressed in terms of radial and axial components:

$F_Q(Z) = F_{xy}(Z)$ x (normalized average axial power at elevation Z)

where:

$F_{xy}(Z)$ = radial peaking factor at elevation Z

$$= \frac{\max.\ power\ density\ at\ elevation\ Z}{avg.\ power\ at\ elevation\ Z}$$

In other words,

$$F_Q(Z) = \frac{\max.\ power\ density\ at\ elevation\ Z}{avg.\ power\ at\ elevation\ Z}$$

multiplied by

$$\frac{avg.\ power\ density\ at\ elevation\ Z}{avg.\ core\ power\ density}$$

$F_{xy}(Z)$ thus characterizes radial peaking at elevation Z. If $F_{xy}(Z)$ is within the limits specified in the COLR for all core elevations, then there is assurance that unacceptable local power densities will not result from axial redistributions of core power. Put another way, satisfying the F_{xy} limits ensure that the core is not operated with a high radial peak at a core elevation where the average power density is low.

The F_{xy} surveillance involves obtaining $F_{xy}(Z)$ values (designated as F_{xy}^{M}) from a flux map for 30 to 75 core elevations and increasing them by the 1.0815 factor described above. The adjusted measured values of $F_{xy}(Z)$ (designated as F_{xy}^{C}) are compared to conservatively chosen radial peaking factor limits, which vary with core elevation and are included in the COLR. If each F_{xy}^{C} is less than the applicable limits at each core elevation, the F_{xy} surveillance is satisfied.

3.4.3.1.2 F_Q Methodology

The F_Q methodology also involves two surveillances for verifying that the $F_Q(Z)$ limits are satisfied. The first surveillance, a comparison of adjusted measured F_Q values (F_Q^{C}) to the $F_Q(Z)$ limits specified in the COLR, is identical to the first F_{xy} methodology surveillance.

Because flux maps are taken at steady-state conditions, a second surveillance is necessary to account for variations in power distribution resulting from normal operational maneuvers. These variations are conservatively calculated by considering a wide range of unit maneuvers in normal operation. Accordingly, W(Z), the maximum peaking factor increase over the steady-state value, is provided as a function of core elevation in the COLR. W(Z) is often provided as a table of multipliers vs. core elevation, as in the TTC Unit 2 COLR. The surveillance involves multiplying the adjusted measured peaking factor, F_Q^{C}, by W(Z) to obtain the maximum $F_Q(Z)$ expected to occur during normal operation, F_Q^{W}. The surveillance is satisfied if F_Q^{W} is less than the F_Q limit at each core elevation. Satisfying this surveillance provides assurance that unacceptable local power densities will not result from normal operational maneuvers.

The action statements for the $F_Q(Z)$ LCO involve reducing thermal power, reducing the power range neutron flux - high and overpower ΔT trip setpoints, and reducing the AFD acceptable operation limits (F_{xy} methodology only).

3.4.3.2 Nuclear Enthalpy Rise Hot Channel Factor

$F^N_{\Delta H}$ is defined as the ratio of the integral of the linear power along the fuel rod with the highest integrated power to the average integrated fuel rod power. Therefore, $F^N_{\Delta H}$ is a measure of the total maximum power produced in a fuel rod. The $F^N_{\Delta H}$ limit identifies the coolant flow channel with the maximum enthalpy rise. This channel has the least heat removal capability and thus has the highest probability for a DNB.

The limit for $F^N_{\Delta H}$ is expressed as:

$$F^N_{\Delta H} \leq 1.65[1.0 + 0.3(1.0 - P)]$$

where:

$$P = \frac{\text{thermal power}}{\text{rated thermal power}}$$

The $F^N_{\Delta H}$ limit is included in the COLR. The value of 1.65 constitutes the maximum allowable $F^N_{\Delta H}$ at 100% power. The limit expression includes an additional margin for higher integrated rod power peaking from reduced thermal feedback and greater control rod insertion at lower power levels. The limiting value for $F^N_{\Delta H}$ increases 0.3% for each 1% reduction in power.

The action statements for the $F^N_{\Delta H}$ LCO call for reducing thermal power and the power range neutron flux - high trip setpoint within a few hours of determining that the limit is exceeded. If the unacceptable condition is not corrected, thermal power must be reduced below 50%, where the $F^N_{\Delta H}$ limit is no longer applicable. Acceptable values of $F^N_{\Delta H}$ must be verified at several points during the subsequent power escalation.

3.4.4 Operational Limits

The technical specification surveillance requirements for the power distribution peaking factors specify that $F_Q(Z)$ and $F^N_{\Delta H}$ are to be verified within their limits every 31 effective full power days. To ensure that each of the peaking factors is maintained within its limit between periodic measurements, the technical specifications provide limits on other parameters which can be readily monitored and controlled by the operators. These parameters include rod position, AFD, and QPTR. Satisfying the LCOs associated with these parameters should maintain the power distribution within limits on a continuous basis between measurements of the peaking factors. The following subsections discuss the operational limits which affect the maintenance of an acceptable core power distribution.

3.4.4.1 Rod Position

Although not included in the power distribution section of the technical specifications, part of the bases for the rod position LCOs is the maintenance of an acceptable power distribution. Compliance with the rod insertion limits helps to ensure that the core's axial power profile is not too highly skewed toward the bottom of the core. The control bank rod insertion limits are included in the COLR. Compliance with the requirement that each rod be operable and positioned within 12 steps of its group's demanded position prevents operation with a dropped or misaligned rod. Significant rod misalignment could result in abnormal radial flux peaking, which may constitute an initial condition inconsistent with the safety analysis.

3.4.4.2 Axial Flux Difference

AFD is defined as the difference in normalized flux signals between the top and bottom halves of a two-section excore neutron detector.

$\text{AFD} = \phi_{\text{top}} - \phi_{\text{bottom}}$

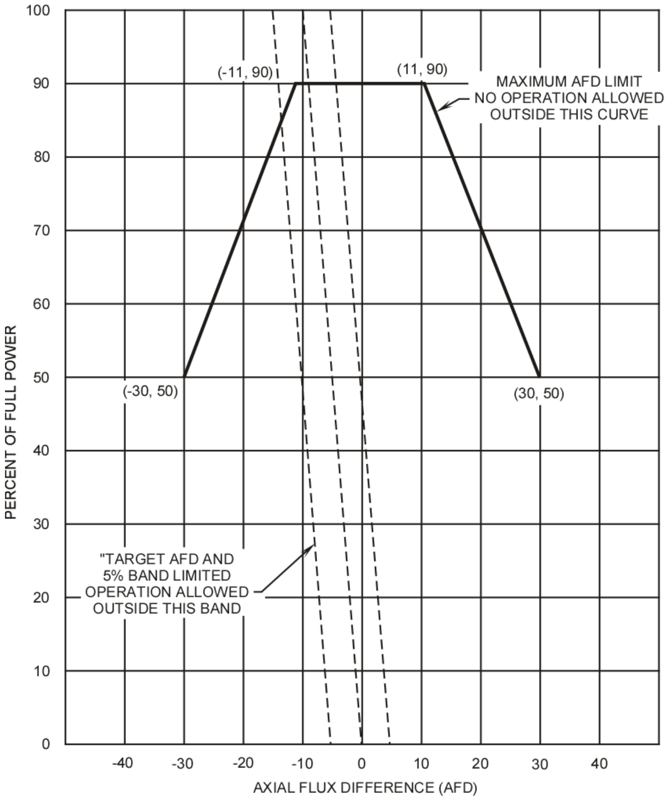
Where ϕ is expressed as a percentage of rated thermal power.

As AFD involves the difference of detector currents, it is often referred to as ΔI.

The limits on AFD limit the amount of power distribution skewing to the top or bottom of the core. The limits on AFD ensure that the $F_Q(Z)$ limits are not exceeded during either normal operation or in the event of xenon redistribution following power changes. The limits on AFD also restrict the range of power distributions that are used as initial conditions in transient and accident analyses.

Two operating schemes are used to control the axial power distribution at Westinghouse plants. These are known as constant axial offset control (CAOC) and relaxed axial offset control (RAOC). RAOC applies to the AFD LCO in the TTC Unit 2 technical specifications. Each operating scheme is described in the following paragraphs.

3.4.4.2.1 Constant Axial Offset Control



CAOC is illustrated in Figure 3.4-2. Such a figure is included in the COLR. CAOC involves maintaining the AFD within a tolerance band around a burnup-dependent target, known as the target flux difference. The target flux difference is determined at equilibrium xenon conditions with power as near to rated thermal power as practical. The control rods are positioned as they normally would be for steady-state operation at high power levels, meaning that the bank D rods are completely or almost completely out of the core. The target flux difference obtained under these conditions, divided by the fraction of rated thermal power at which the flux difference is determined, is the target flux difference at rated thermal power for the associated core burnup conditions. Target flux differences for other power levels are obtained by multiplying the rated thermal power value by the appropriate fractional power level.

Periodic updating of the target flux difference value is necessary to follow the change of the flux difference at steady-state conditions with fuel burnup. The target flux difference at rated thermal power generally shifts from more negative to more positive with burnup in accordance with the general pattern of fuel depletion as the core ages.

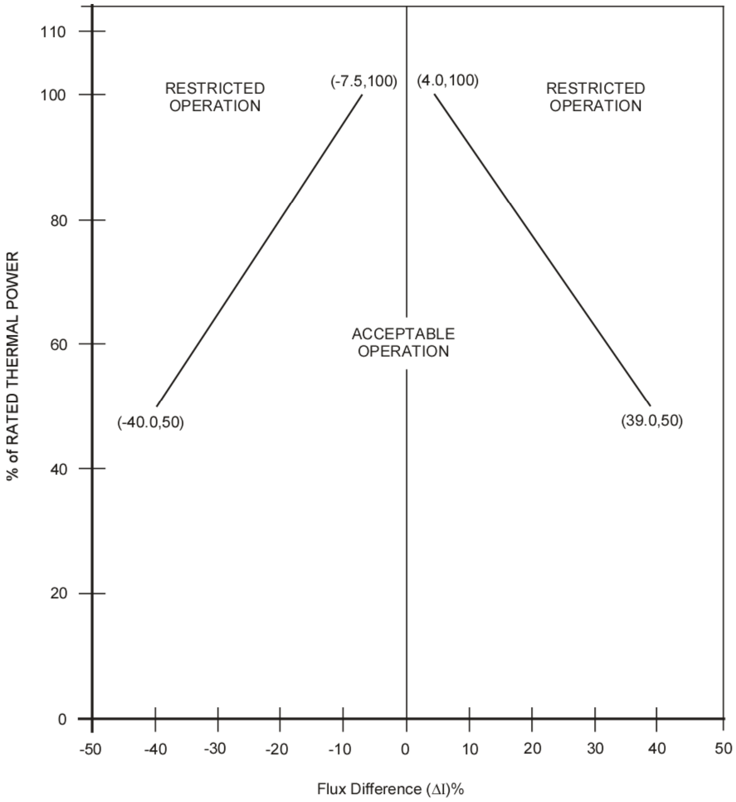
For power levels greater than 90%, the AFD must be kept within the target band. With the AFD outside the target band with power greater than 90%, the assumptions of accident analyses may be violated. Accordingly, above 90% power the AFD must be restored to within the target band almost immediately to avoid a potentially severe xenon redistribution.

However, during rapid power reductions, control bank motion may cause the AFD to deviate outside the target band at reduced power levels. This deviation does not affect the xenon distribution sufficiently to change the envelope of peaking factors that may be reached on a subsequent return to rated thermal power with the AFD within the target band, provided that the time duration of the deviation is limited. Accordingly, a one-hour deviation limit cumulative during the previous 24 hours is provided for operation outside the target band but within the acceptable operation limits. The region of acceptable operation is illustrated in Figure 3.4-2; it is often referred to as “the doghouse” because of its shape. The deviation penalty time is accumulated at the rate of one minute for each minute of operating time spent outside the target band at power levels greater than 50%.

For power levels between 15% and 50%, AFD deviations outside the target band are less significant. Below 50% power, deviation penalty time is accumulated at the rate of 1/2 minute per minute of operating time spent outside the target band.

With power between 50% and 90% and with the AFD either outside the acceptable operation limits or outside the target band for more than one hour of cumulative deviation penalty time during the previous 24 hours, power must be quickly brought to less than 50%. With power less than 50% and with the AFD outside the target band for more than one hour of cumulative deviation penalty time during the previous 24 hours, thermal power cannot be increased equal to or greater than 50% until the AFD is within the target band.

3.4.4.2.2 Relaxed Axial Offset Control



The AFD limits presented in the TTC Unit 2 COLR and shown in Figure 3.4-3 illustrate RAOC. The RAOC methodology establishes a xenon distribution library with tentatively wide AFD limits. Axial power distribution calculations are then performed to demonstrate that normal-operation power shapes are acceptable for the LOCA and loss of flow accident and for the initial conditions of anticipated transients. The tentative limits are adjusted as necessary to meet the safety analysis requirements. Although RAOC defines the limits that must be met to satisfy the safety analyses, CAOC (with a specified AFD target band) is typically used to control the axial power distribution on a day-to-day basis. The CAOC operating space typically lies within the RAOC operating space.

The AFD LCO under RAOC methodology does not include a target band or the potential for accumulated deviation penalty time, but the plant operating instructions typically include a target band for normal operation. The LCO action statements simply call for restoring the AFD to within the acceptable operation region or reducing power to less than 50%.

3.4.4.3 Quadrant Power Tilt Ratio

QPTR is defined as the ratio of the maximum upper excore detector calibrated output to the average of the upper excore calibrated outputs, or the ratio of the maximum lower excore detector calibrated output to the average of the lower excore calibrated outputs, whichever is greater.

The word “calibrated” in the definition reflects the fact that a full incore/excore calibration returns QPTR to a value of 1. Thus, a QPTR of > 1.02 indicates gross changes in core power distribution between monthly incore flux maps.

In other words, QPTR is not an absolute measure of anything. It is a relative measure that indicates changes in the gross radial power distribution since the most recent incore/excore calibration. If QPTR = 1, this does NOT indicate that the radial power distribution is perfectly flat. It simply indicates that there have been no significant changes since the last incore/excore calibration.

With a QPTR greater than the limit (typically 1.02), the QPTR must be restored to within its limit within two hours, or thermal power must be reduced at least 3% for each 1% of QPTR in excess of 1.00. Since this indicates significant changes in power distribution since the last incore/excore calibration, another flux map is performed (i.e. a verification that $F_Q(Z)$ and $F^N_{\Delta H}$ are within their limits). If the flux map indicates acceptable results, an incore/excore calibration is performed per REQUIRED ACTION A.5, which returns QPTR to a value 1.0. The two-hour time allowance for operation with a QPTR greater than the limit allows for identification and correction of a dropped or misaligned rod.

With operation above 75% power and one excore channel inoperable, the movable incore detectors are used to confirm that the power distribution is consistent with the QPTR indicated by the remaining three excore channels.

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3.4.5 Exercises

Exercise 1

An incore flux map is obtained with the plant at 95% power in accordance with a regularly scheduled surveillance. Core burnup is 150 MWD/MTU. Measured values of the heat flux hot channel factor, $F_Q^M(Z)$, at three core elevations are as follows:

Elevation (ft)	F_Q^M (Z)
4	1.8176
6	1.8549
10	1.7932

1. Calculate F_Q^C (Z) for each core elevation.
2. Calculate F_Q^W(Z) for each core elevation.
3. Determine whether the F_Q(Z) limit has been exceeded.
4. State the actions to be taken in accordance with technical specification requirements.

Exercise 2

With reactor power at 100%, it is noted that the current AFD value is − 8.3%.

1. State the actions to be taken in accordance with technical specification requirements.
2. State how the operator would restore the AFD to within the limits.

Exercise 3

While the plant is operating at 98% power, the following annunciators alarm: ROD BOTTOM, ROD DEVIATION POWER TILT, and POWER RANGE COMPARATOR DEVIATION. The digital rod position indication system indicates that one rod is on the bottom. The calculated QPTR immediately after the rod drop is 1.05.

1. State the actions to be taken in accordance with technical specifications.
2. State the basis for the 2-hour completion time for reducing thermal power.

Exercise 4

With reactor power at 90%, state the requirements for verifying the QPTR:

1. Under normal circumstances.
2. When the QPTR alarm is inoperable.

3. When one power range channel is inoperable.

TECHNICAL SPECIFICATIONS UNIT 4 - EXERCISE 1 SOLUTION

1. Calculate $F_Q^C(Z)$ for each core elevation.

Calculate each $F_Q^C(Z)$ by multiplying the measured value by 1.0815 to account for manufacturing tolerances and flux map measurement uncertainty.

Elevation (ft)	$F_Q^M(Z)$	x 1.0815 =	$F_Q^C(Z)$
4	1.8176		1.9657
6	1.8549		2.0061
10	1.7932		1.9393

2. Calculate $F_Q^W(Z)$ for each core elevation.

Calculate each $F_Q^W(Z)$ by multiplying $F_Q^C(Z)$ by the W(Z) value for the applicable core elevation. Obtain W(Z) values from Figure COLR-3 for the stated core burnup.

Elevation (ft)	$F_Q^C(Z)$	x	W(Z) =	$F_Q^W(Z)$
4	1.9657		1.2365	2.4306
6	2.0061		1.2049	2.4171
10	1.9393		1.3090	2.5386

3. Determine whether the $F_Q(Z)$ limit has been exceeded.

Determine the $F_Q(Z)$ limit for each core elevation with the formula provided in the COLR (CFQ = 2.50, P = 0.95) and the appropriate K(Z) value from Figure COLR-2. Then compare each $F_Q^C(Z)$ and $F_Q^W(Z)$ value to the applicable limit.

Elevation (ft)	CFQ/P	x	K(Z)	=	$F_Q(Z)$ limit
4	2.6316		1.000		2.6316
6	2.6316		1.000		2.6316
10	2.6316		0.950		2.5000

The $F_Q^W(Z)$ value at the 10-ft elevation (2.5386) exceeds the $F_Q(Z)$ limit (2.5000).

1. State the actions to be taken in accordance with technical specification requirements.

Condition B of LCO 3.2.1 applies. In accordance with action B.1, the AFD limits must be reduced at least 1% for each 1% by which $F_Q^W(Z)$ exceeds the limit within 2 hours.

$F_Q^W(Z)$ exceeds the limit by $(\frac{2.5386-2.5}{2.5})\times 100 = 1.544\%$

Round up to 2% for conservatism. AFD limits at 95% power (see Figure COLR-8):

Lower limit: $-40+\frac{(95-50)(-7.5-(-40)}{100-50} = -10.75$

Upper limit: $39+\frac{(95-50)(4-39)}{100-50} = 7.5$

Add 2% to lower limit and subtract 2% from upper limit. New AFD bounds at 95% power are (-8.75, 5.5). If this action is not taken within 4 hours, then the plant must be brought to MODE 2 (where LCO 3.2.1 does not apply) within the next 6 hours, per action C.1.

TECHNICAL SPECIFICATIONS UNIT 4 - EXERCISE 2 SOLUTION

1. State the actions to be taken in accordance with technical specification requirements.

Condition A of LCO 3.2.3 applies. Power must be reduced to < 50% within 30 minutes if the AFD is not corrected to within the limits during that time.

2. State how the operator would restore the AFD to within the limits.

Since the AFD is too negative, the control rods are probably too deeply inserted; the operator would restore the AFD by borating the reactor coolant to drive the control rods farther out.

TECHNICAL SPECIFICATIONS UNIT 4 - EXERCISE 3 SOLUTION

1. State the actions to be taken in accordance with technical specifications.

Condition A of LCO 3.2.4 applies. The required actions associated with condition A must be taken. In the short term, power would be reduced to 85% (a 15% reduction from RTP because the QPTR exceeds 1.00 by 5%) in accordance with action A.1, unless the QPTR is made less than 1.02 within 2 hours. In addition, the periodic QPTR checks specified by action A.2 should alert the operators to a worsening QPTR condition, which would mandate further power reductions. Additional actions have longer completion times.

2. State the basis for the 2-hour completion time for reducing thermal power.

The basis for required action A.1 states, “The Completion Time of 2 hours allows sufficient time to identify the cause [of the QPTR exceeding its limit] and correct the tilt.”

TECHNICAL SPECIFICATIONS UNIT 4 - EXERCISE 4 SOLUTION

With reactor power at 90%, state the requirements for verifying the QPTR:

1. Under normal circumstances.

Surveillance requirement (SR) 3.2.4.1 requires verifying the QPTR by calculation once every 7 days.

2. When the QPTR alarm is inoperable.

The QPTR alarm has no significance in technical specification. The surveillance interval is still 7 days.

3. When one power range channel is inoperable.

SR 3.2.4.2 requires verifying the QPTR using the movable incore detectors once within 12 hours and once every 12 hours thereafter with one power range channel inoperable and power $\geq$ 75%.

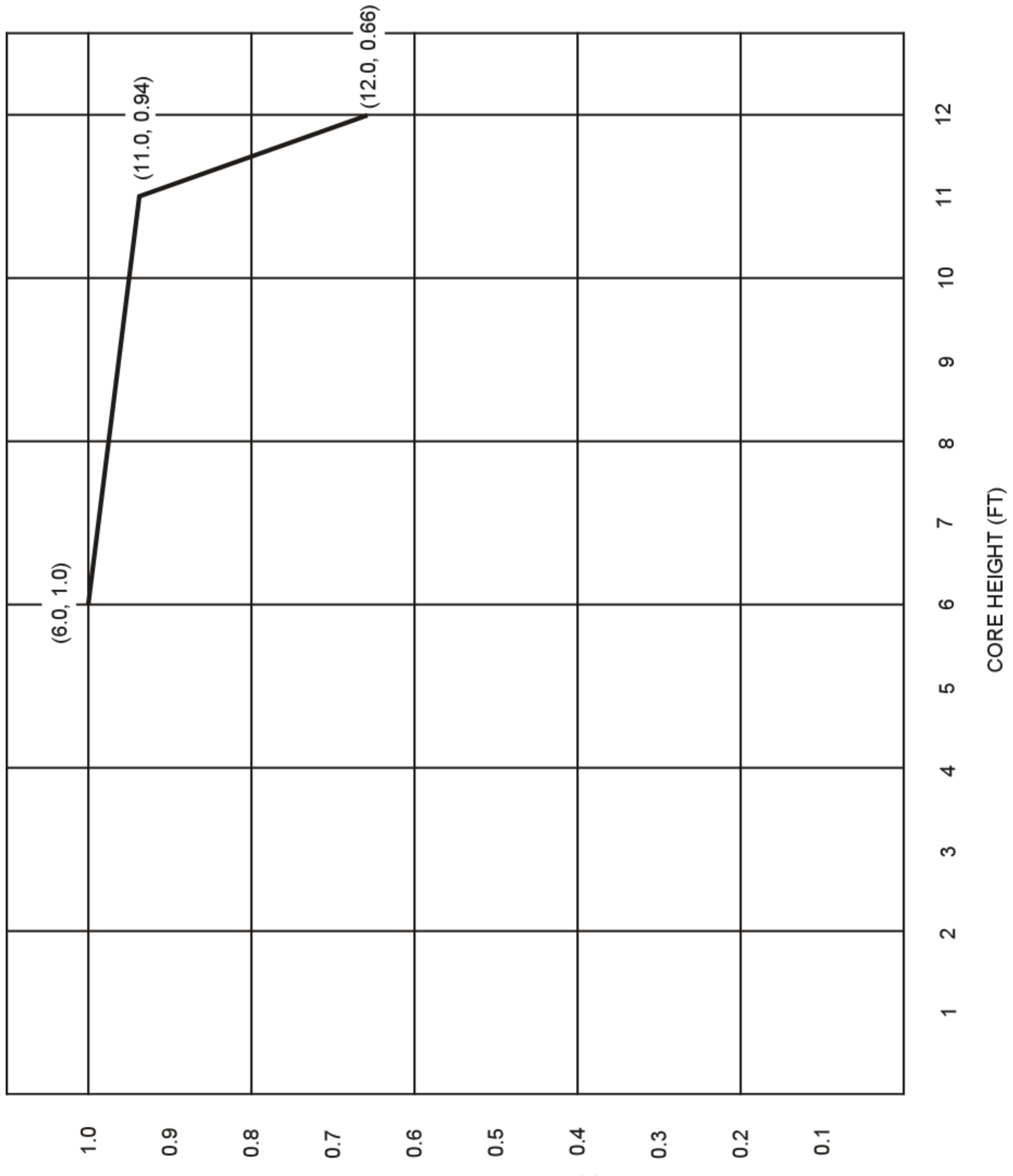

Figure 3.4-1 K(Z) Correction Term

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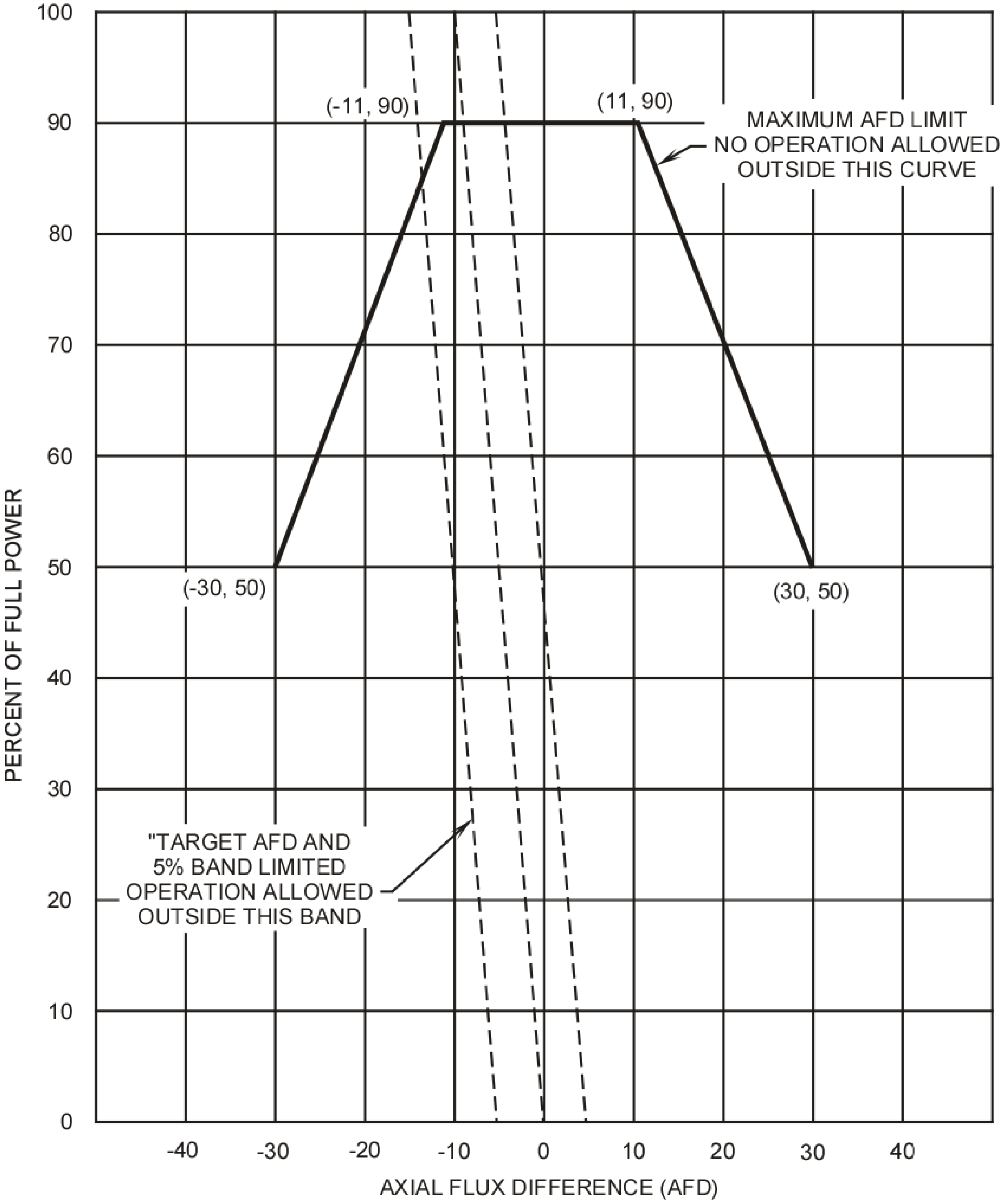

Figure 3.4-2 Axial Flux Difference Limits , CAOC

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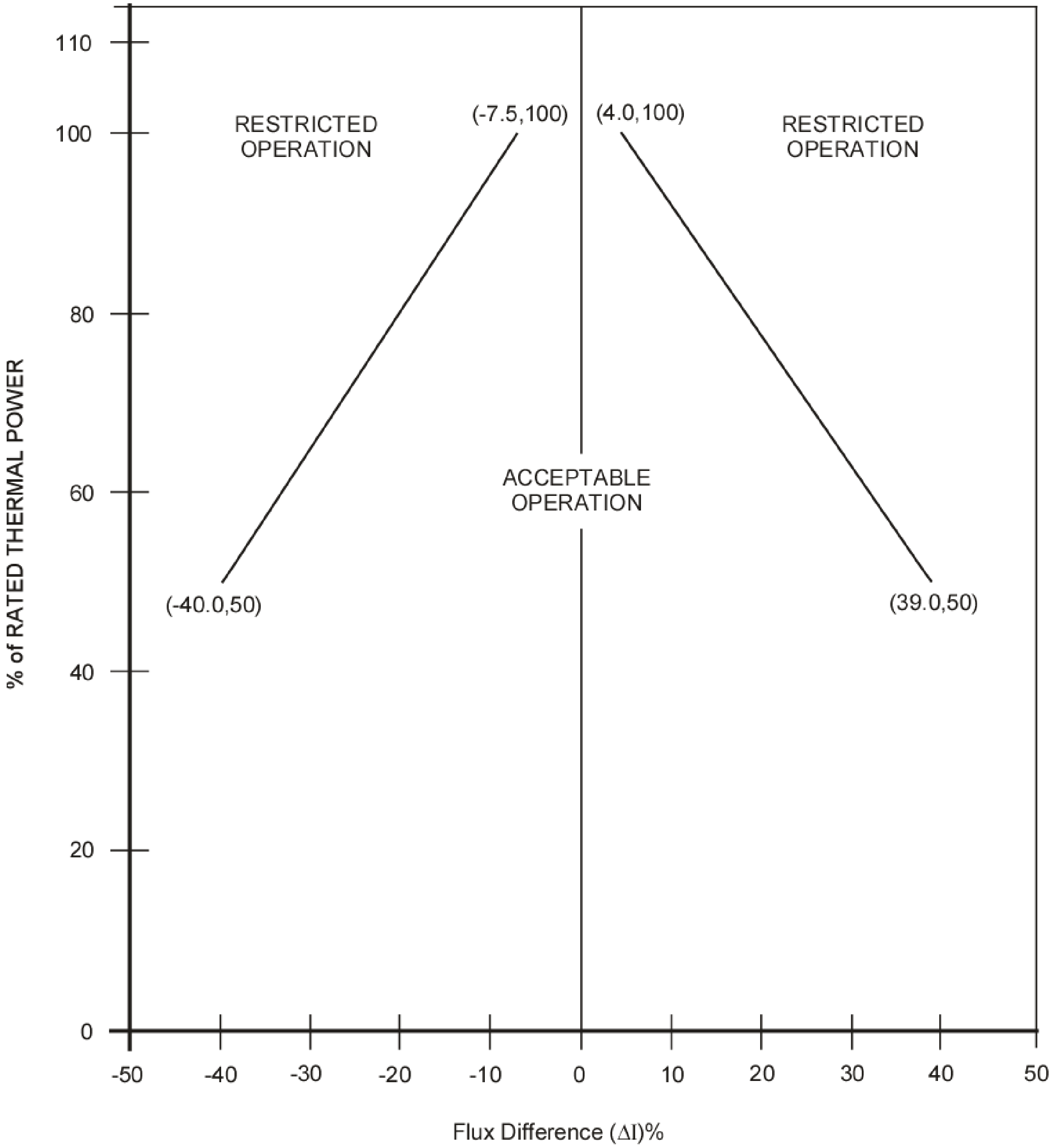

Figure 3.4-3 Axial Flux Difference, RAOC