



Plant Operating Limits

Chapter 22.0
B&W Cross-Training Course
R-326C

OBJECTIVES

1. Define the following terms:
 - a. Axial Power Imbalance (API).
 - b. Rod Index.
 - c. Quadrant Power Tilt (QPT)
 - d. Heat Flux Hot Channel Factor - $F_Q(Z)$
 - e. Enthalpy Rise Hot Channel Factor - $F_{\Delta H}^N$

OBJECTIVES

2. Describe how the API Operating Limits and QPT Limits relate to the measurement system independent limits, and how they vary when different measurement instruments are used.
3. Explain the bases for:
 - a. Core Safety Limits.
 - b. Power Distribution Limits.

Safety Limits

- TS 2.1.1- Rx Core Safety Limits (Modes 1 & 2)
 - Max. local fuel pin centerline temperature \leq limit.
 - DNBR $>$ limit.
 - RCS core outlet temperature/pressure shall be maintained w/in limits of DNB Figure.
- TS 2.1.2- RCS Pressure Safety Limit (Modes 1 – 5)
 - RCS pressure $<$ 2750 psig.

Safety Limits (2)

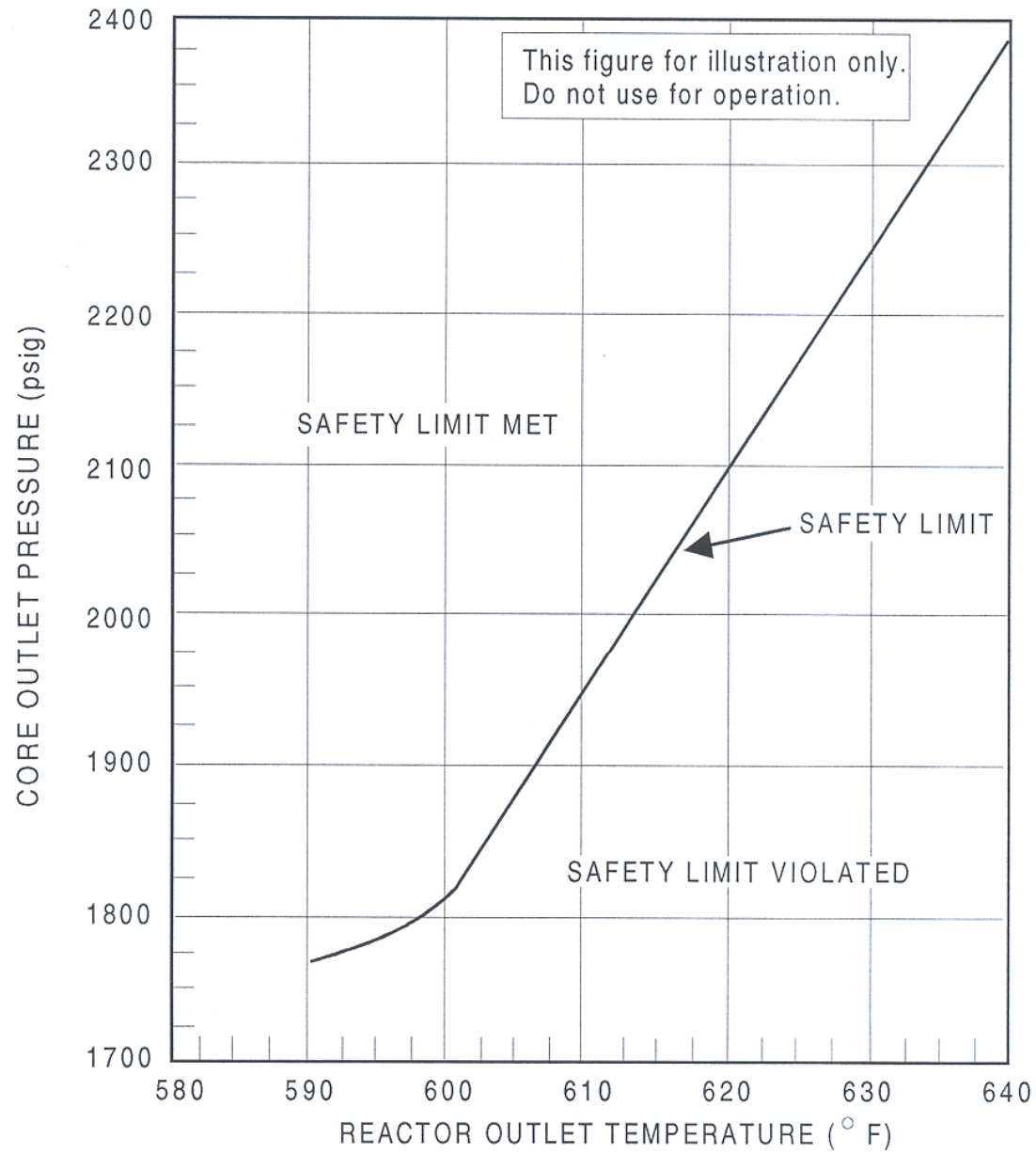
- Operation w/in the RCS temperature/pressure operating region keeps the Rx from reaching a Safety Limit.
- Proper operation of RPS and the S/G code safeties prevents violation of the Core Safety Limits.

Safety Limits ⁽³⁾

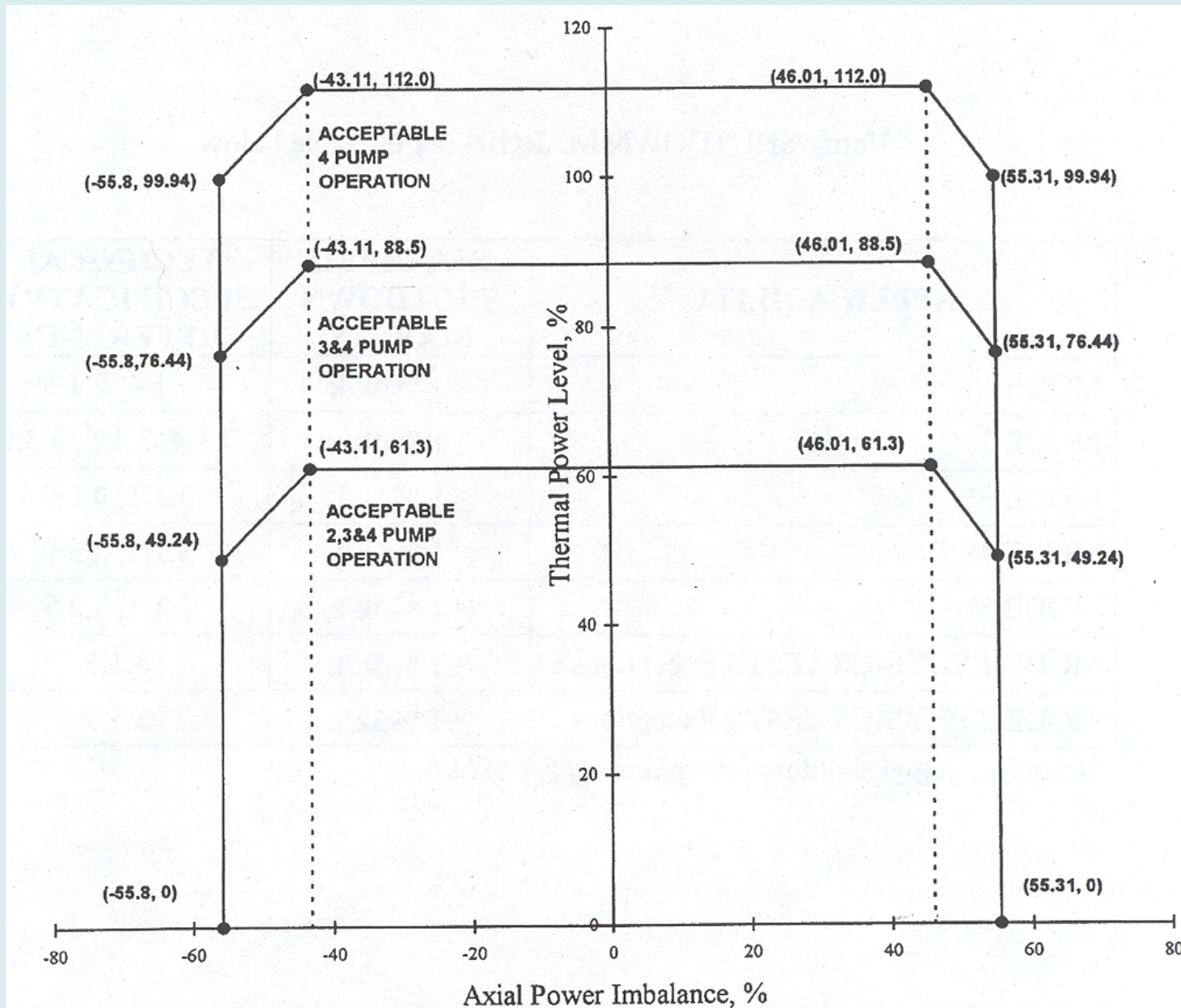
- Core SLs are preserved by compliance w/ the Axial Power Imbalance (API) Protective Limits.
- API:(% of Rate Thermal Power (RTP) in upper half of core) – (% of RTP in lower half of core)
 - a.k.a. axial flux distribution (or offset).
- API Protective Limits in COLR.
- If plant conditions stay w/in the RPS trip setpoints, then API Protective Limits will not be exceeded.

Safety Limits (4)

- Recall that satisfying the Safety Limits prevents damage to fuel and/or cladding during normal operations and AOOs.
- However, satisfying the Safety Limits does not ensure that the fuel /clad will not be damaged during accidents.
 - If the plant operates w/in the Power Distribution Limits, then fuel/cladding damage limited during accidents.



RCS Temperature/Pressure Safety Limits (Fig. 22-1)



Typical API Protective Limits (Measurement System Independent)

Fig. 22-2

API Protective Limits

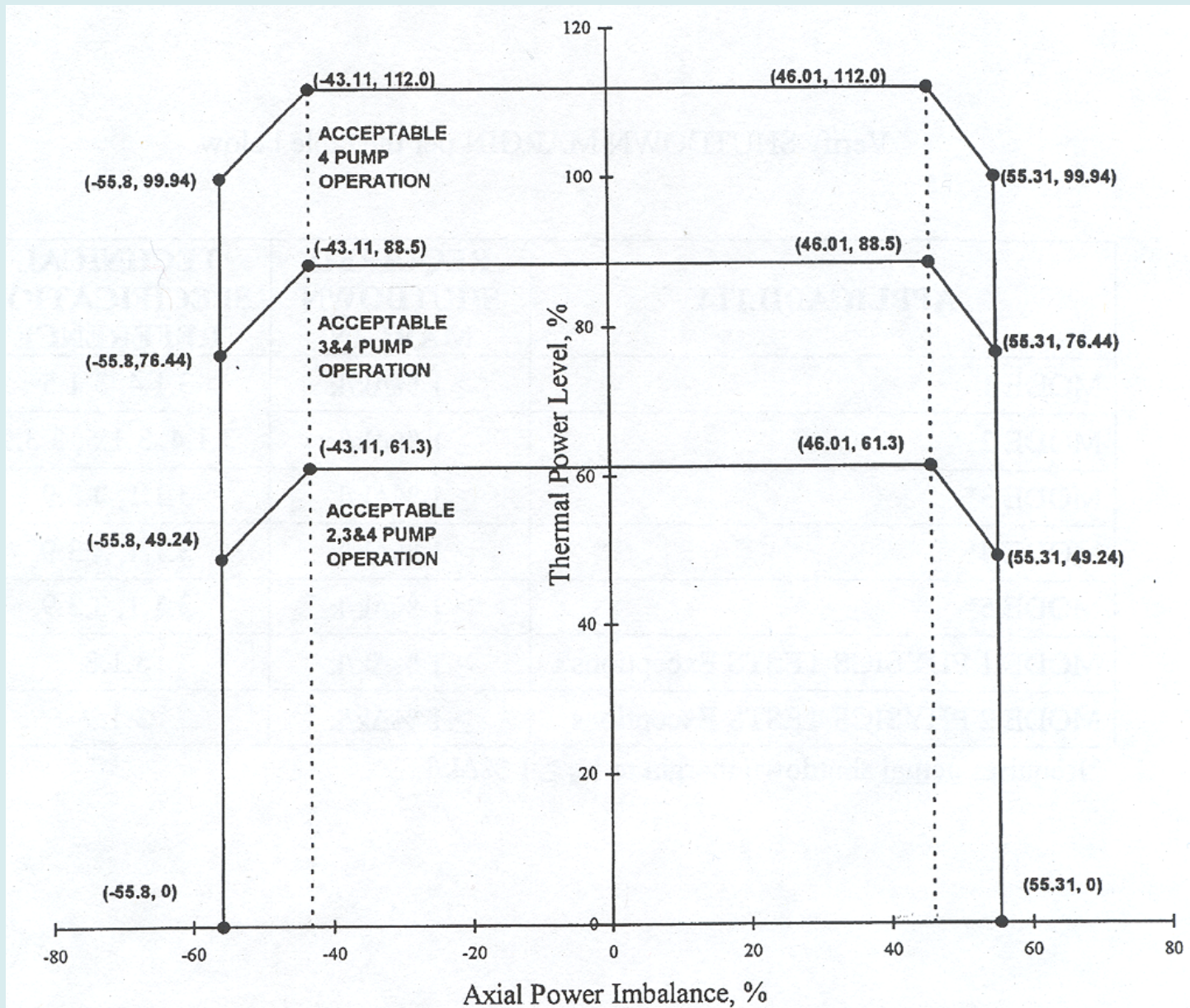
- Different limits for different RCP combinations.
- If operation within Protective Limits, fuel design criteria not exceeded.
- Measurement System Independent limits are determined from core reload analysis.
- Protective limits are least restrictive boundaries that will maintain the Safety Limits.

API RPS Setpoints

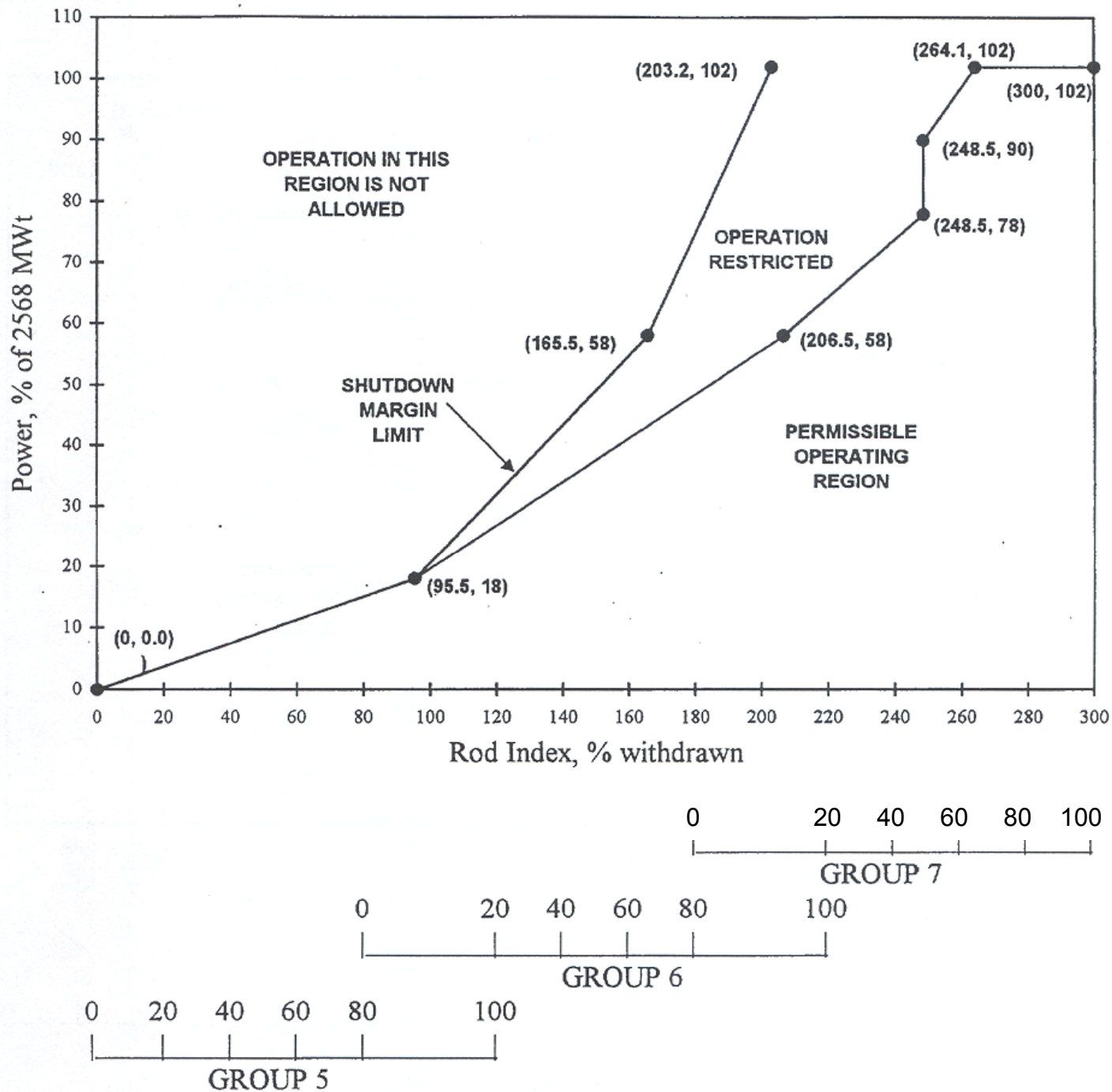
- API RPS Trip setpoint are more restrictive than API Protective Limits.
 - Must account for instrument errors & uncertainties and for measurement system observability.
- Different max. allowable RPS setpoints for different RCP combinations (RCS flows).

Power Distribution Limits (TS 3.2)

- Power Distribution limits support compliance with Core Safety Limits by maintaining local core conditions within design limits.
- Power Distribution limits are operating limits which establish the initial conditions assumed in accident analysis.



Typical API RPS Trip Setpoints (Fig. 22-3)



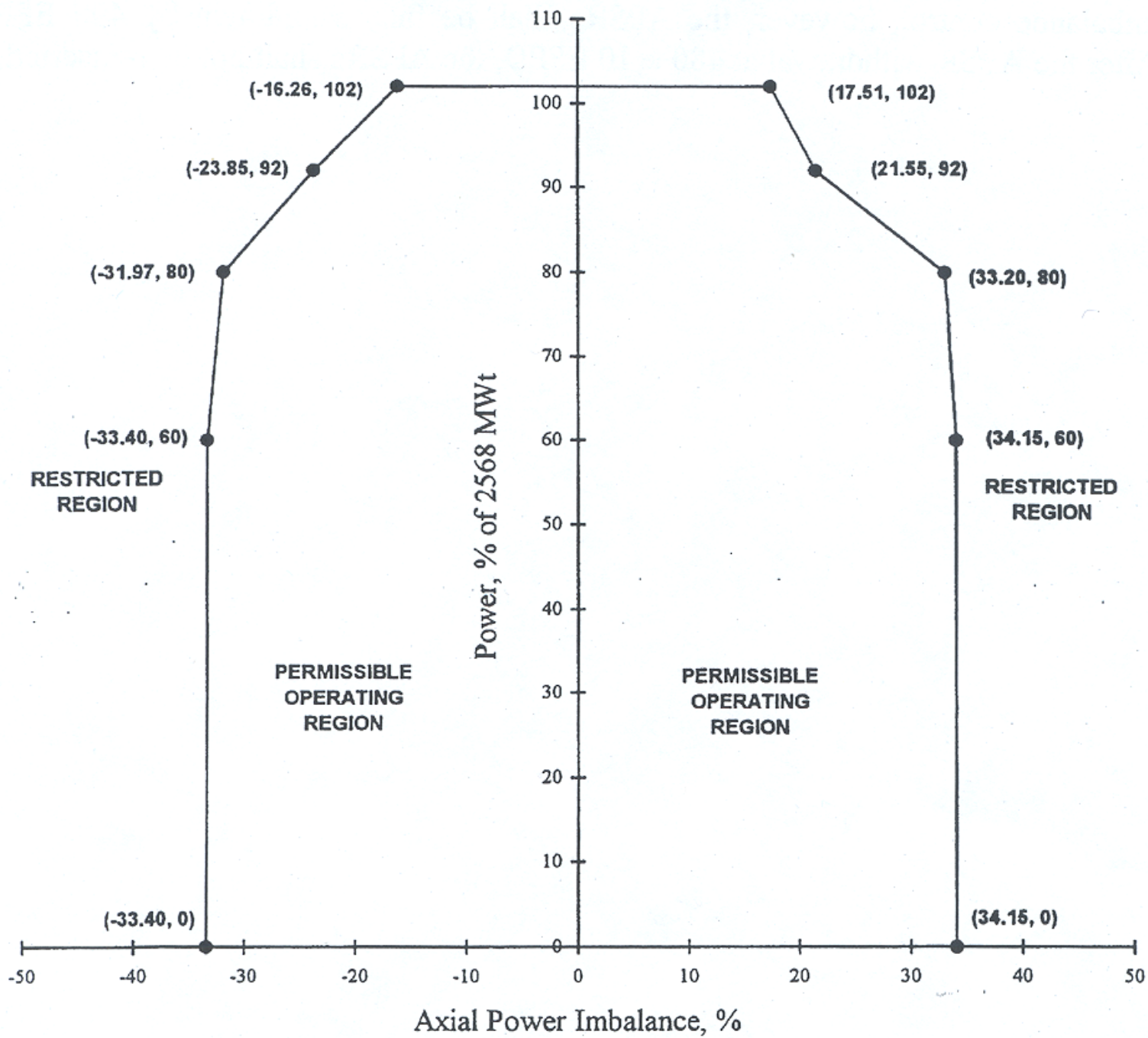
Typical
Regulating Rod
Insertion
Limits
(4 RCPs)
Fig. 22-4

Regulating Rod Insertion Limits

- Sequence, overlap and insertion limits in COLR.
 - Maintain adequate SDM.
 - Minimize effects of ejected rod.
 - Maintain power distribution within range of analyzed distributions.
- Different curves for different times in core life and for different pump combinations.
 - Limits are a family of curves.

APSR Insertion Limits

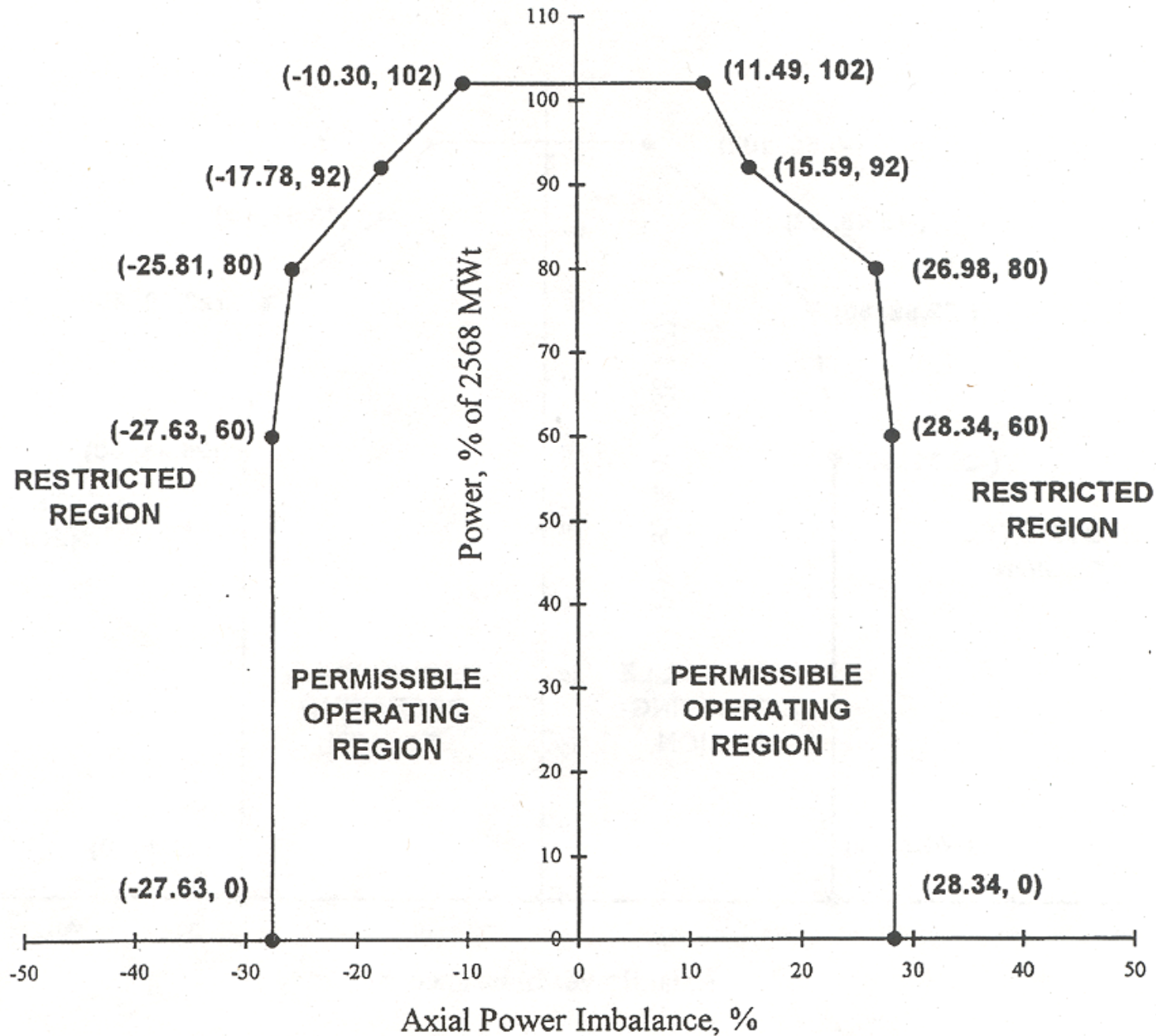
- APSRs positioned as necessary for API control.
- Later in core life, maximum insertion limits apply
 - (usually fully withdrawn).
- Ensures axial flux distribution is consistent w/ design and accident analysis.



Typical
API
Operating
Limits
Full-Incore
Conditions
(4 RCPs)
Fig. 22-5

API Operating Limits

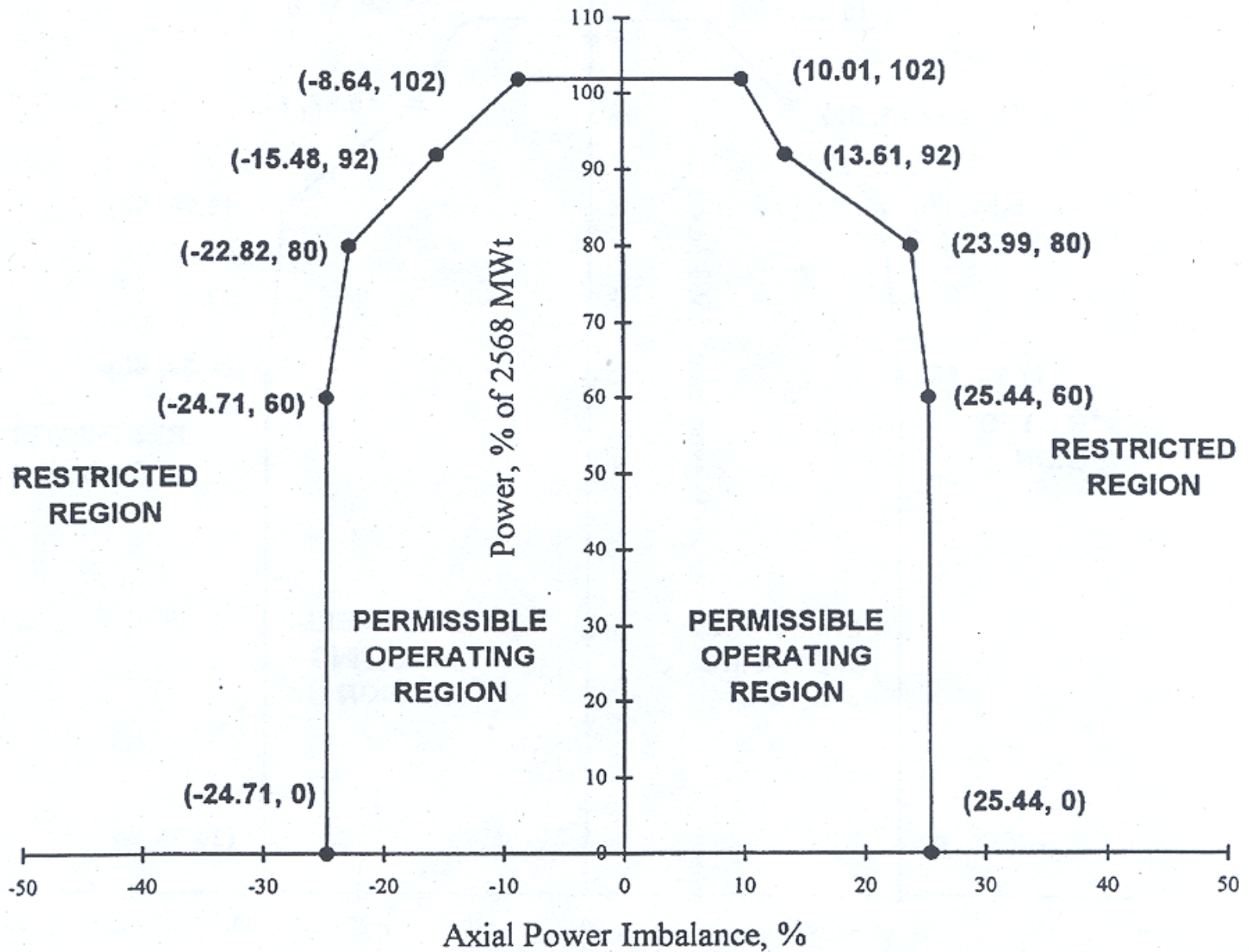
- API (measurement system independent) Protective Limits - least restrictive boundaries that will maintain the Safety Limits.
- API RPS Setpoints - more restrictive than API Protective Limits.
 - Must account for instrument errors & uncertainties and for measurement system observability.
- API Operating Limits – most restrictive.
 - API envelope in COLR represents points where power distribution would exceed LOCA LHR limits or cause reduction in DNBR below safety limit during loss-of-flow accident.
 - Different limits for different RCP combinations.



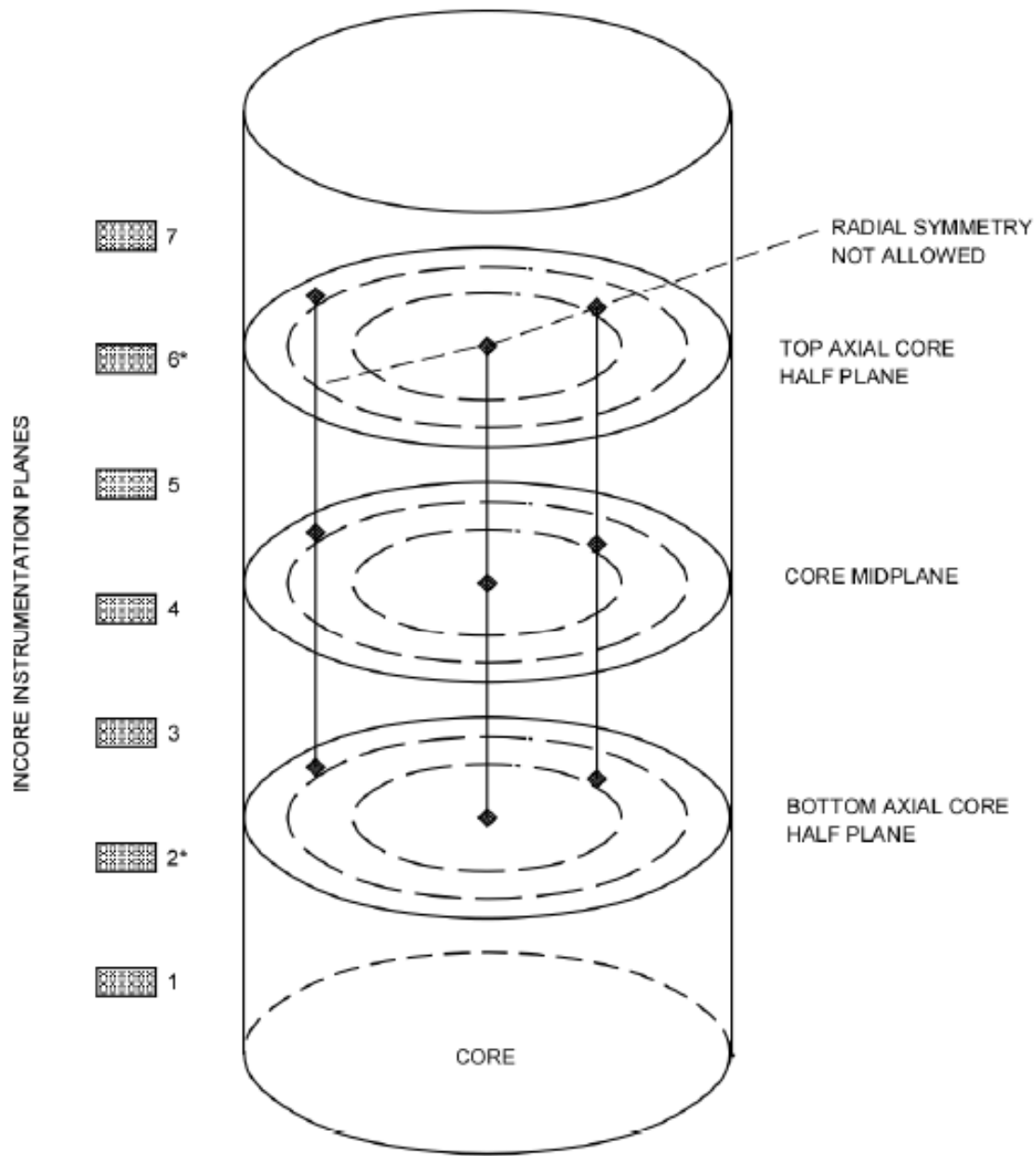
Typical API Operating Limits – Excore Conditions (4 RCPs) (Fig. 22-6)

API Operating Limits ⁽²⁾

- API can be measured by both Excore NIs and Incore instruments.
- Not only have different limits for different RCP combinations, but also have different limits depending on how the variable is measured.
 - Adjusts for measurement uncertainties.
 - Full Incore conditions – least restrictive.
 - Excore conditions – more restrictive.
 - Minimum Incore conditions – most restrictive.



Typical API Operating Limits – Minimum Incore Conditions (4 RCPs)
Fig. 22-7



* PLANES
2 AND 6 ARE
AXIALLY
SYMMETRICAL

Minimum Incore System Conditions for API Measurement Fig. 22-8

Quadrant Power Tilt (QPT)

$$QPT = 100\% \left[\frac{\textit{power in any quadrant}}{\textit{average power in all quadrants}} - 1 \right]$$

- QPT can be measured by both excore NIs and Incore instruments.
- Has different limits depending on how the variable is measured.
 - Adjusts for measurement uncertainties.

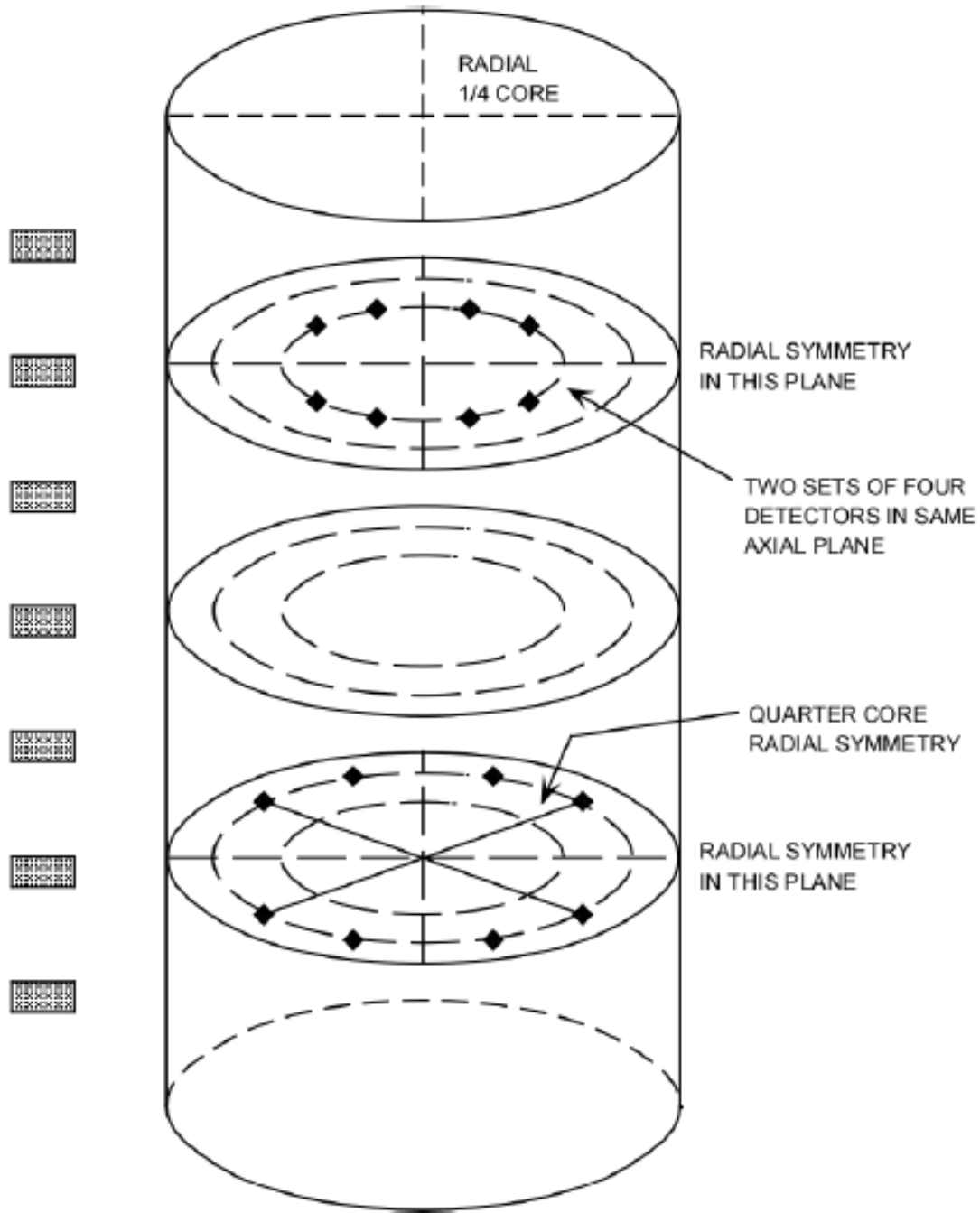
QPT

- Measurement System Independent– least restrictive.
 - determined from core reload analysis.
 - Not all plants.
- Full Incore (symmetric) conditions – more restrictive.
- Excure conditions – even more restrictive.
- Minimum Incore conditions – most restrictive.

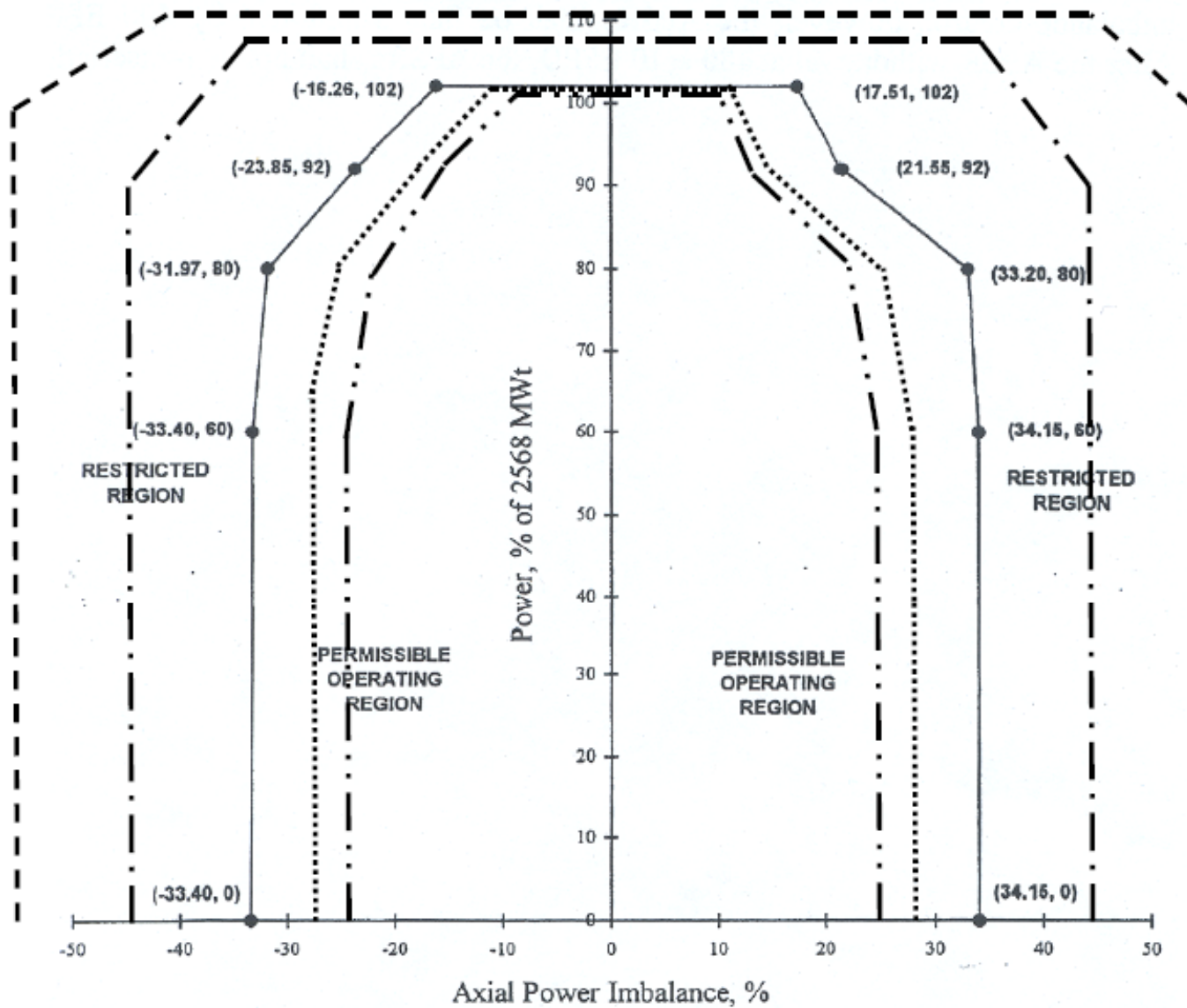
Peaking Factors ⁽¹⁾

- Peaking Factor TS establish limits on power density so that fuel design criteria are not exceeded and accident analysis assumptions remain valid.
 - $F_Q(Z)$ – Heat Flux Hot Channel Factor
 - $F_{\Delta H}^N$ - Enthalpy Rise Hot Channel Factor

INCORE INSTRUMENTATION PLANES



Minimum Incore
Detector System for
QPT Measurement
Fig. 22-9



- API Protective Limits (Measurement System Independent)
- . - . - API RPS Trip Setpoints
- API Operating Limits - Full Incore Conditions
- API Operating Limits - Excore Conditions
- . . - . API Operating Limits - Minimum Incore Conditions

Composite Family
of Curves for
Typical API Limits
(4 RCPs)
Fig. 22-10