TMI-1 Cycle 10
Core Operating Limits Report

TOPICAL REPORT 099
Rev. 1

BA Number 135400

TMI-1 Cycle 10 Reload Task Force
March, 1995

APPROVALS:

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Originator — Date

3/14/95
Cycle 10 Reload Task Force Chairman — Date

John X. [illegible] — 3/14/95
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G.R. Bond — 3-16-95
Director, Nuclear Analysis & Fuel — Date

M A Nelson (PSO) — 3/21/95
Plant Review Group — Date

GPU Nuclear

DOCUMENT NO: TR 099

TITLE: TMI-1 CYCLE 10 CORE OPERATING LIMITS REPORT

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	LOCA limits in Figure 7 were reduced by 1.0 and 1.3 kw/ft at the 2' level for MkB8 and MkB9 fuel, respectively. Conservative high burnup fuel CMS kw/ft monitoring limits administratively installed in Table 2 at BOC were replaced with BWFC-recommended fresh fuel limits (adjusted for the 2' level reductions) from 400-661 EFPD. New references added.	Robert Jaffa [illegible]	3-10-95 3/14/95

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A0000038 12-83

ABSTRACT

This Core Operating Limits Report (COLR) has been prepared in accordance with the requirements of TMI-1 Technical Specification 6.9.5. The core operating limits were generated using the methodologies described in References 12 through 31 and were documented in References 1 through 5. The information in this COLR was reviewed for use at TMI-1 in References 6 through 11.

The Full Incore System (FIS) operability requirements contained within describe the number and location of Self-Powered Neutron Detector (SPND) strings that must be operable in order to monitor imbalance and quadrant tilt using the FIS.

Quadrant tilt limits for FIS, out-of-core detector [OCD] system and minimum incore system [MIS] are given in Table 1.

Table 2 is discussed below with Figure 7.

Rod position limits are provided in Figures 1 to 3 to ensure that the safety criteria for DNBR protection, LOCA kw/ft limits, shutdown margin and ejected rod worth are met.

Imbalance limits for FIS, OCD and MIS are given in Figures 4 to 6.

COLR Figures 1 through 6 may have three distinctly defined regions:

1. Permissible Region
2. Restricted Region
3. Not Allowed Region (Operation in this region is not allowed)

Inadvertent operation within the Restricted Region for a period not exceeding four (4) hours is not considered a violation of a limiting condition for operation. The limiting criteria within the Restricted Region are potential ejected rod worth and ECCS power peaking. Since the probability of these accidents is very low, especially in a four (4) hour time frame, inadvertent operation within the Restricted Region for a period not exceeding four (4) hours is allowed.

COLR Figure 7 indicates the LOCA limited maximum allowable linear heat rates as a function of fuel rod burnup and fuel elevation for Mark B8 and Mark B9 fuel. Bounding values for monitoring these limits for the current cycle in terms of cycle burnup and axial detector levels are listed in Table 2.

COLR Figure 8 provides the Axial Power Imbalance Protective Limits (APIPL) that preserve the DNBR and Centerline Fuel Melt design criteria.

COLR Figure 9 provides the Protection System Maximum Allowable Setpoints for Axial Power Imbalance which combine the power/flow and error-adjusted axial imbalance trip setpoints that ensure the APIPL of Figure 8 are not exceeded.

Enclosure 1 contains operating limits not required by TS, but monitored by the Process Computer Nuclear Applications Software as part of the bases of the required limits and setpoints. These include the core minimum DNBR and the Maximum Allowable Local Linear Heat Rate Limits.

Enclosure 2 contains the bases descriptions of the Power-to-Flow Trip Setpoint to prevent violation of DNBR criteria and the Design Nuclear Power Peaking Factors for axial flux shape (F^N_Z) and hot channel nuclear enthalpy rise ($F^N_{\Delta H}$) that define the reference design peaking condition in the core.

TABLE OF CONTENTS

References:

Main Body

1. BAW-2187 Rev. 0, "Three Mile Island Unit 1 Cycle 10 Reload Report," May 1993.

2. BWFC Doc. No. 86-1223246-00, "TMI-1 Cycle 10 Limits & Setpoints," August 1993.

3. BWFC Doc. No. 62-1224552-00, "Power Escalation Test Specification TMI-1 Cycle 10," August, 1993.

4. BWNT Doc. No. 51-1234870-00, "TMI-1 Cycle 11 Task 4 Reload," K.S. Pacheco, dated January 19, 1995.

5. GPUN Calc. No. C-1101-202-5412-219, Rev. 0, "TMI-1 Cycle 10 Revised NAS MALHR Alarm Setpoints," R. Jaffa, February, 1995.

6. GPUN Safety Evaluation 135400-017, Rev. 2, "TMI-1 Cycle 10 Reload Design," May, 1994.

7. GPUN Safety Evaluation 135400-013, Rev. 0, "Tech Spec LOCA Limit Changes," June 28, 1991.

8. GPUN Safety Evaluation 135425-006, Rev. 0, "Tech Spec 6.9.5.2 Reference to BAW-10179P (TSCR 225)," May 3, 1993.

9. GPUN Safety Evaluation 135400-019, Rev. 0, "Removal of Axial Power Imbalance Protective Limits and Setpoints from TS to COLR," September, 1993.

10. GPUN Safety Evaluation, 135400-020, Rev. 0, "TMI-1 Cycle 10 Core Operating Limits Report," March, 1995.

11. BWFC Doc. No. 12-1235309-00, "Operating Limit Evaluation for PSC 5-94," B. Delano, December 13, 1994.

Methodology

12. BAW-10122A, Rev. 1, "Normal Operating Controls," May 1984.

13. Letter from J. H. Taylor (B&W) to J. A. Norberg (NRC), "Extended Lifetime Incore Detector Error Allowances," April 21, 1988, JHT/88-28.

14. BWFC Doc. No 86-1172640-00, "Detector Lifetime Extension Final Report for TMI-1," September 1988.

15. GPUN Safety Evaluation 000622-001, Rev. 1, "Control Rod API and RPI 24 Month Cycle Extension," April 16, 1992.

16. BAW-10116-A, "Assembly Calculations and Fitted Nuclear Data," May 1977.

17. BAW-10118A, "Core Calculational Techniques and Procedures," December 1979.

References (continued):

18. BAW-10119A, "Power Peaking Nuclear Reliability Factors," February 1979.

19. BAW-10120P-A, "Comparison of Core Physics Calculations with Measurements," March 1978.

20. BAW-10180A, Rev. 1, "NEMO-Nodal Expansion Method Optimized,"March 1993.

21. BAW-10141P-A, Rev. 1, "TACO-2 Fuel Pin Performance Analysis," June 1983.

22. BAW-10162P-A, "TACO-3 Fuel Pin Thermal Analysis Computer Code," November 1989.

23. BAW-10184P-A, "GDTACO, Urania-Gadolinia Thermal Analysis Code," May 1992.

24. BAW-10103A, Rev. 3, "ECCS Analysis of B&W's 177-FA Lowered Loop NSS," July 1977.

25. BAW-1775, "TACO Loss-of Coolant Accident Limit Analysis for 177-FA Lowered Loop Plants," February 1983.

26. BAW-1915P-A, "Bounding Analytical Assessment of NUREG-0630 Models on LOCA kw/ft Limits With Use of FLECSET," November 1988.

27. BAW-10104P-A, Rev. 5, "B&W ECCS Evaluation Model," November 1988.

28. BAW-10179P-A, Rev. 0, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," February 1991.

29. BAW-2119-A, "Evaluation of Replacement Rods in BWFC Fuel Assemblies," December 1991.

30. BAW-10143P-A, "BWC Correlation of Critical Heat Flux", April 1985.

31. BAW-10156A "LYNXT: Core Transient Thermal Hydraulic Program", February 1986.

Full Incore System (FIS)
Operability Requirements

- The Full Incore System (FIS) is operable for monitoring axial power imbalance provided the number of valid Self Powered Neutron Detector (SPND) signals in any one quadrant is not less than 75% of the total number of SPNDs in the quadrant.

Quadrant	SPNDs	75%
WX	85.75	64.5
XY	99.75	75.0
YZ	89.25	67.0
ZW	89.25	67.0

- The Full Incore System (FIS) is operable for monitoring quadrant tilt provided the number of valid symmetric string individual SPND signals in any one quadrant is not less than 75% (21) of the total number of SPNDs in the quadrant (28).

Quadrant	Symmetric Strings
WX	7, 9, 32, 35
XY	5, 23, 25, 28
YZ	16, 19, 47, 50
ZW	11, 13, 39, 43

Source Doc.: B&W 86-1172640-00
Referred to by: Tech. Spec. 3.5.2.4.a and 3.5.2.7.a

Table 1
Quadrant Tilt Limits

	Steady State Limit 15% < Power ≤ 50%	Steady State Limit Indicated Power > 50%	Maximum Limit Indicated Power > 15%
Full Incore System (FIS)	6.83%	4.20%	16.8%
Out-of-Core Detector System (OCD)	4.05%	1.96%	14.2%
Minimum Incore System (MIS)	2.80%	1.90%	9.5%

Source Docs.: B&W 86-1223246-00
Referred to by: Tech. Spec. 3.5.2.4

Table 2

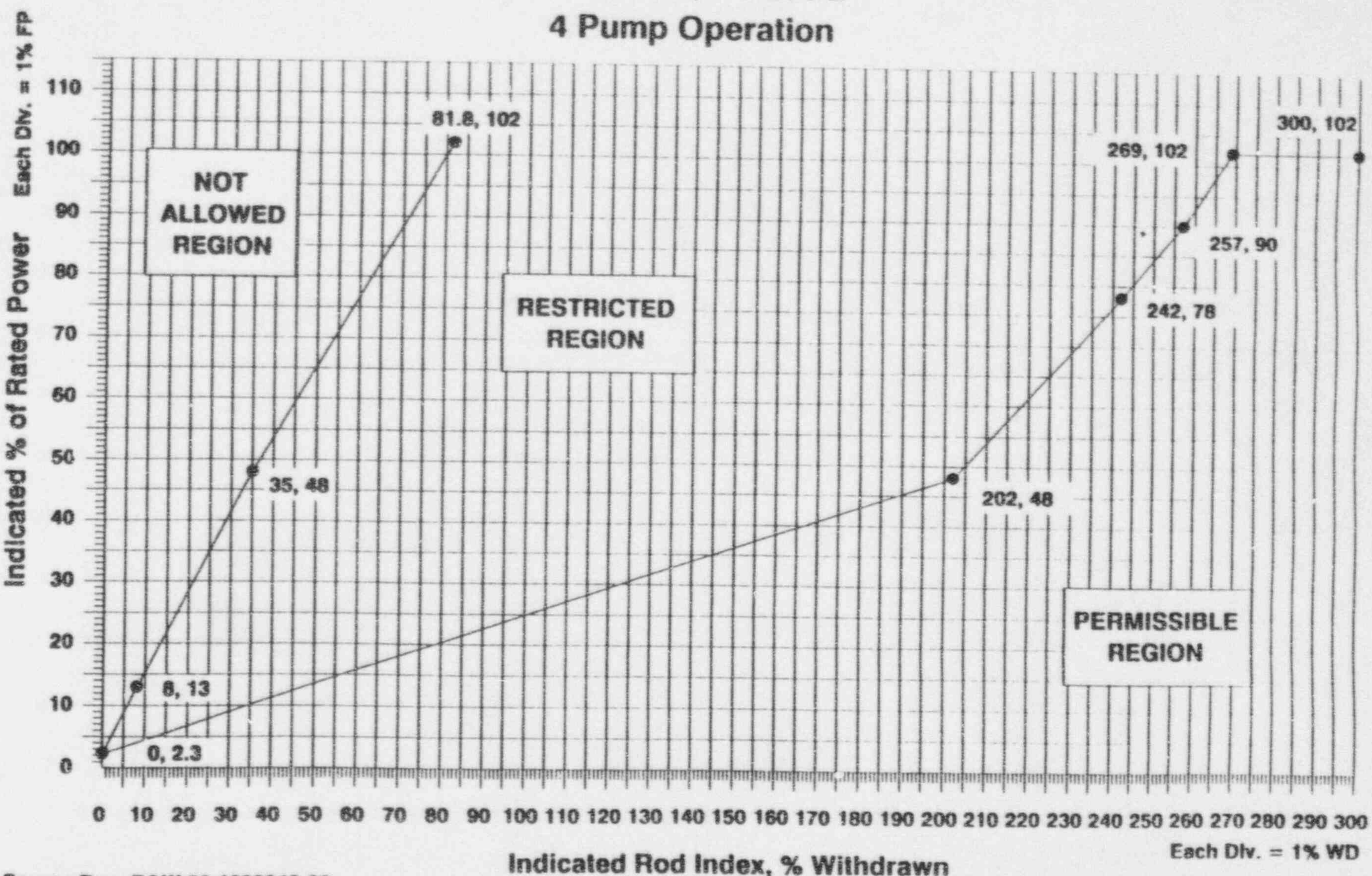
Core Monitoring System Bounding Values for LOCA Limited Maximum Allowable Linear Heat Rate
(kW/ft)

CMS Level	0-75 EFPD	75-300 EFPD	300-400 EFPD	400-661 EFPD
8	11.6	11.2	10.8	12.8
7	13.8	13.3	12.8	15.2
6	14.5	14.0	13.5	16.1
5	14.5	14.0	13.5	16.1
4	14.5	14.0	13.5	16.1
3	14.5	14.0	13.5	15.0
2	13.7	13.2	12.8	13.8
1	11.6	11.2	10.8	11.6

The maximum linear heat rate for each CMS level, as measured with the NAS Thermal Hydraulic Package (Display 4), should be less than the corresponding bounding value from Table 2 above.

Source Docs.: B&W Doc. No. 62-1224552-00
GPUN Calc. No. C-1101-202-5412-219, Rev. 0

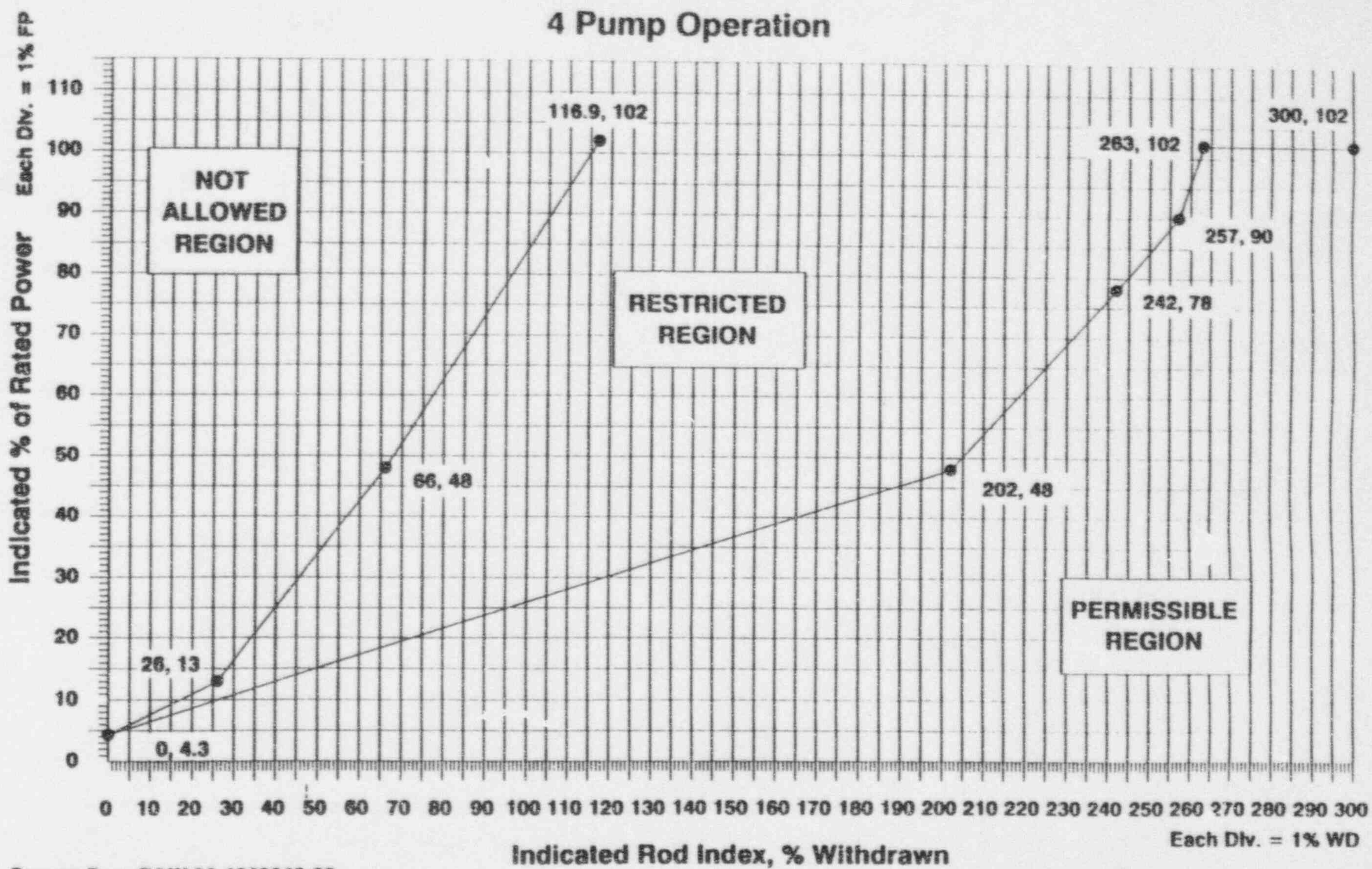
Figure 1 (Page 1 of 3)
Error Adjusted Rod Insertion Limits
0 to 75 +0/-10 EFPD
4 Pump Operation



Source Doc. B&W 86-1223246-00

Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

Figure 1 (Page 2 of 3)
Error Adjusted Rod Insertion Limits
75 +0/-10 to 400 +/- 10 EFPD
4 Pump Operation



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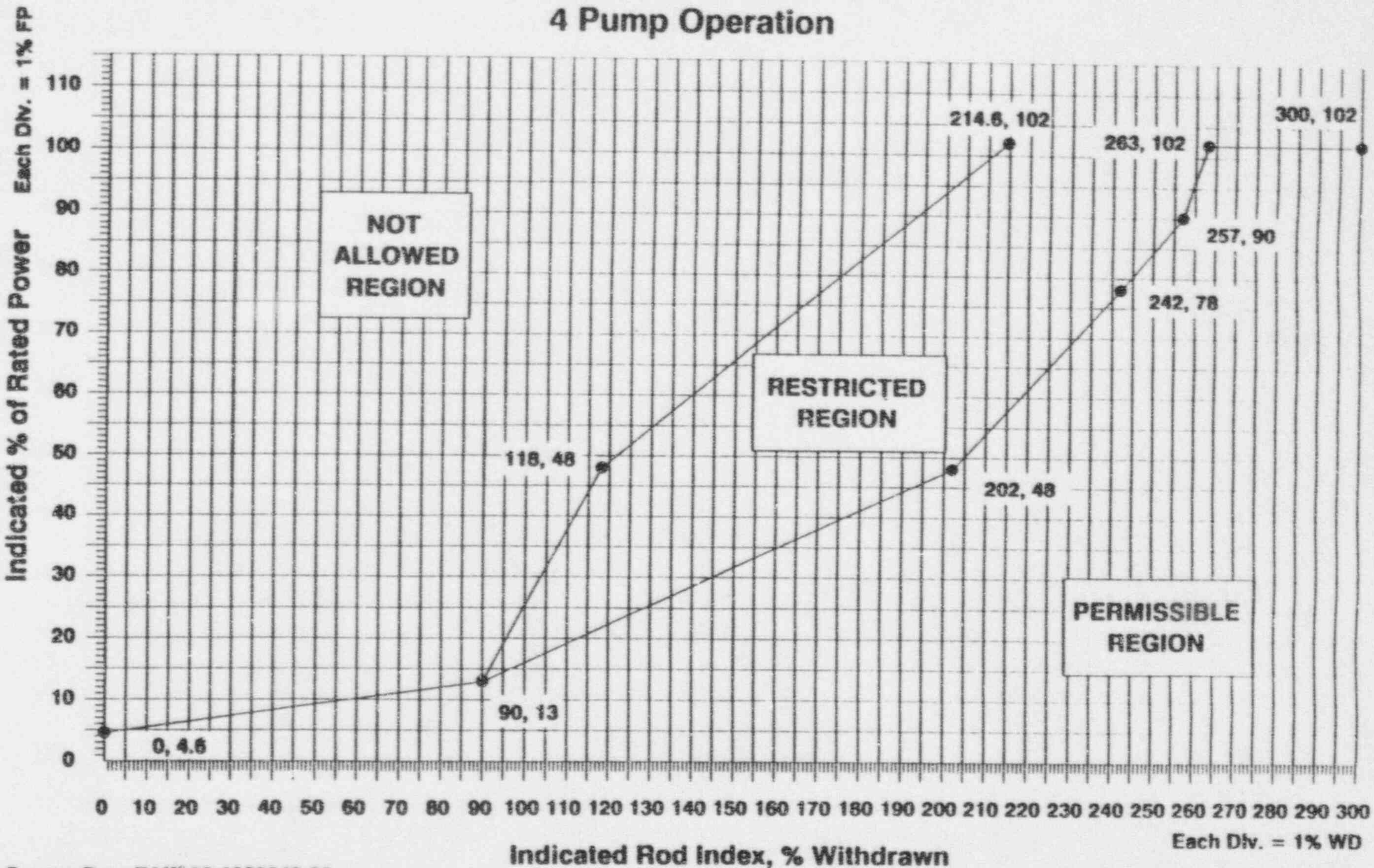
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

Figure 1 (Page 3 of 3)
Error Adjusted Rod Insertion Limits
400 +/-10 EFPD to EOC
4 Pump Operation



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Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

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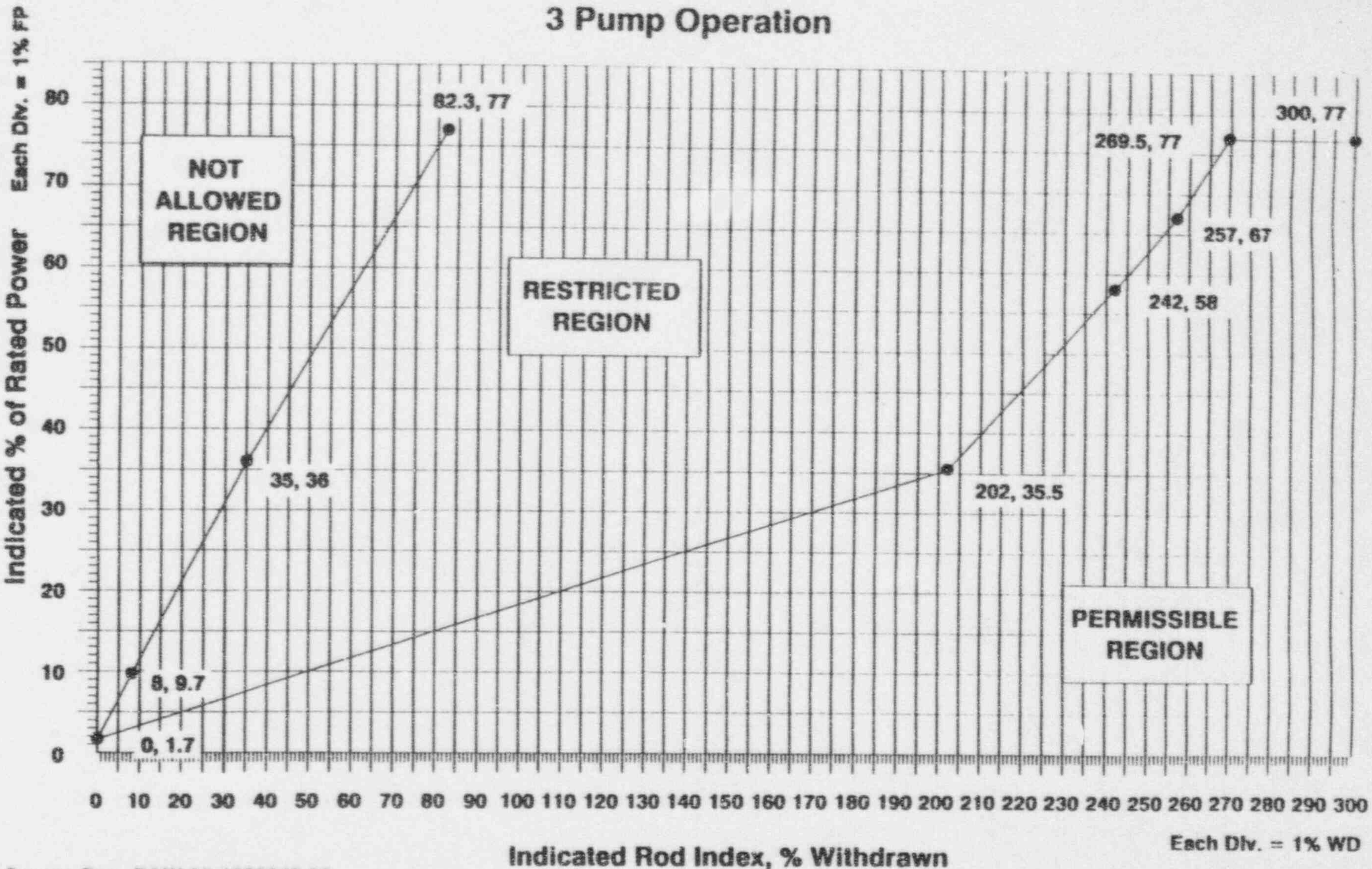
Error Adjusted Rod Insertion Limits
0 to 75 +0/-10 EFPD
3 Pump Operation



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Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

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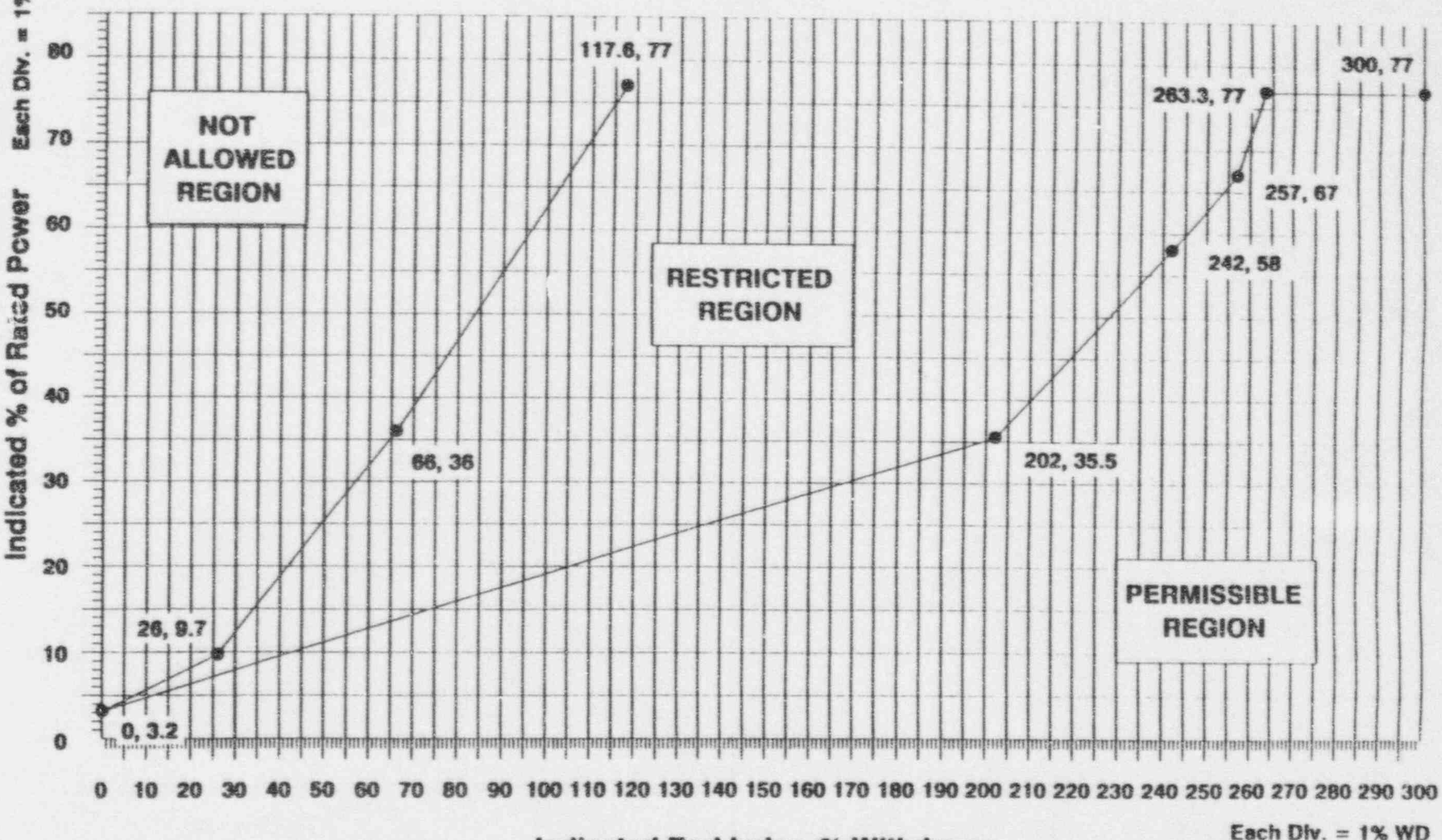
Error Adjusted Rod Insertion Limits
75 +0/-10 to 400 +/-10 EFPD
3 Pump Operation



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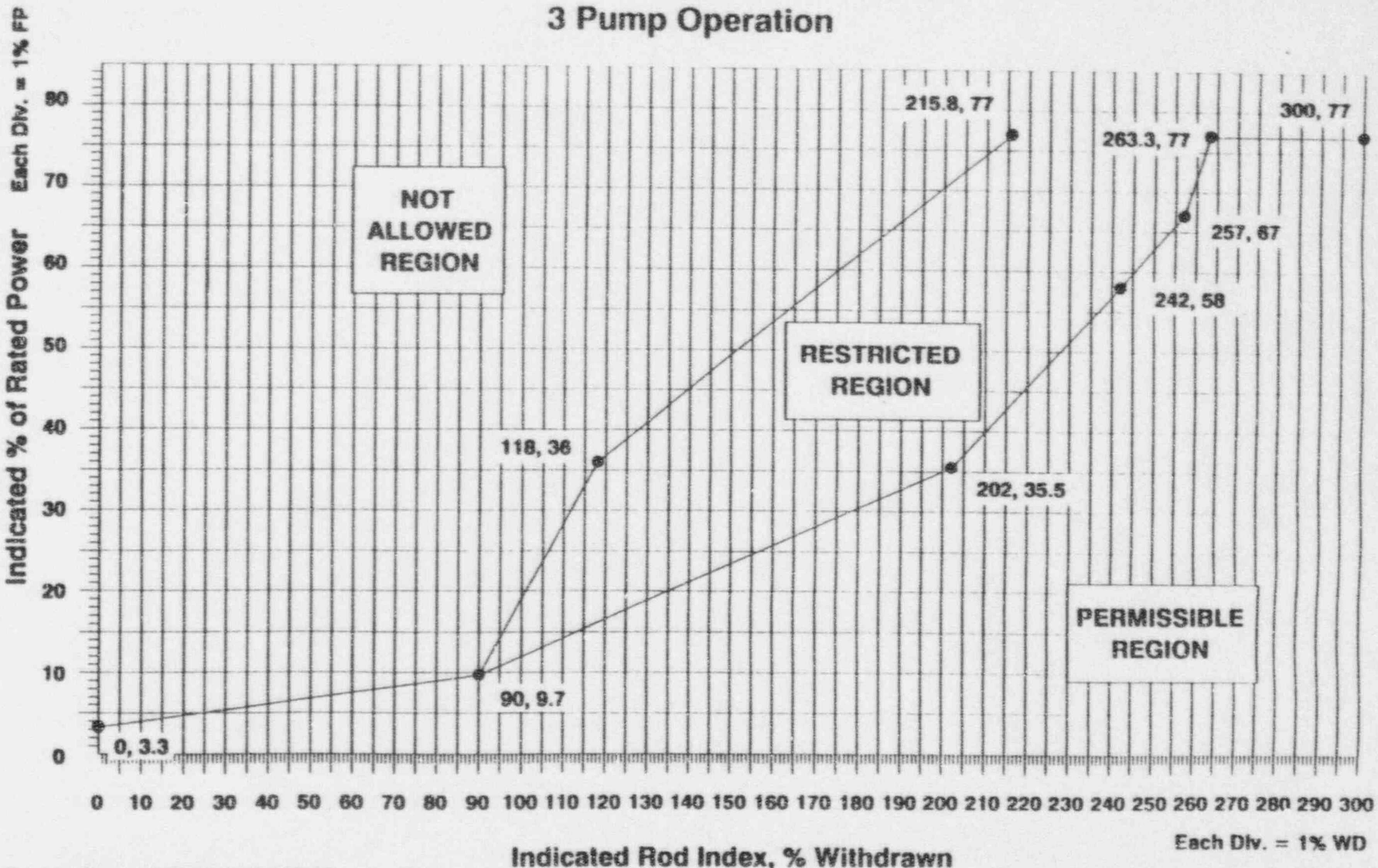
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

Figure 2 (Page 3 of 3)
Error Adjusted Rod Insertion Limits
400 +/-10 EFPD to EOC
3 Pump Operation



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Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2

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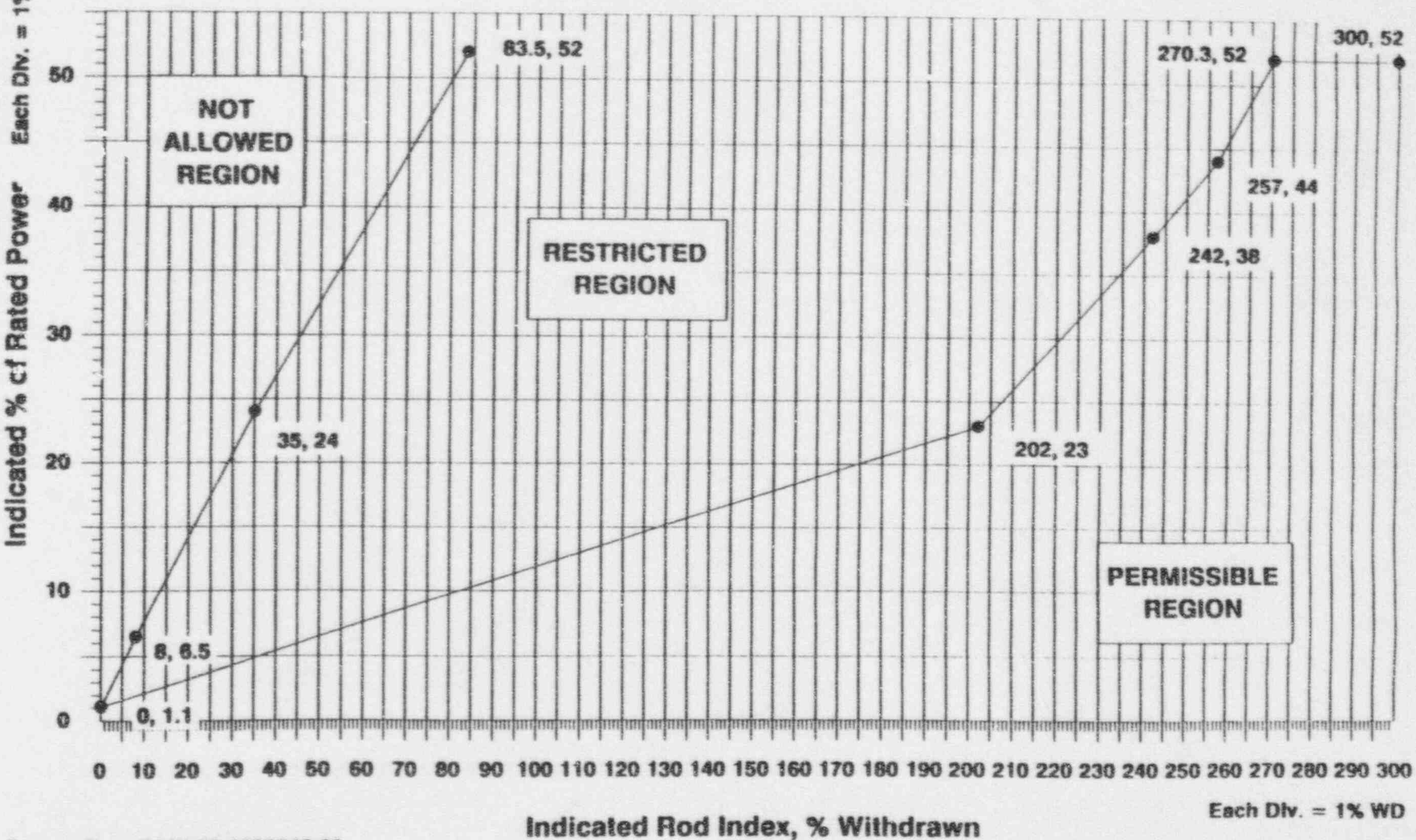
0 to 75 +0/-10 EFPD
2 Pump Operation



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Error Adjusted Rod Insertion Limits
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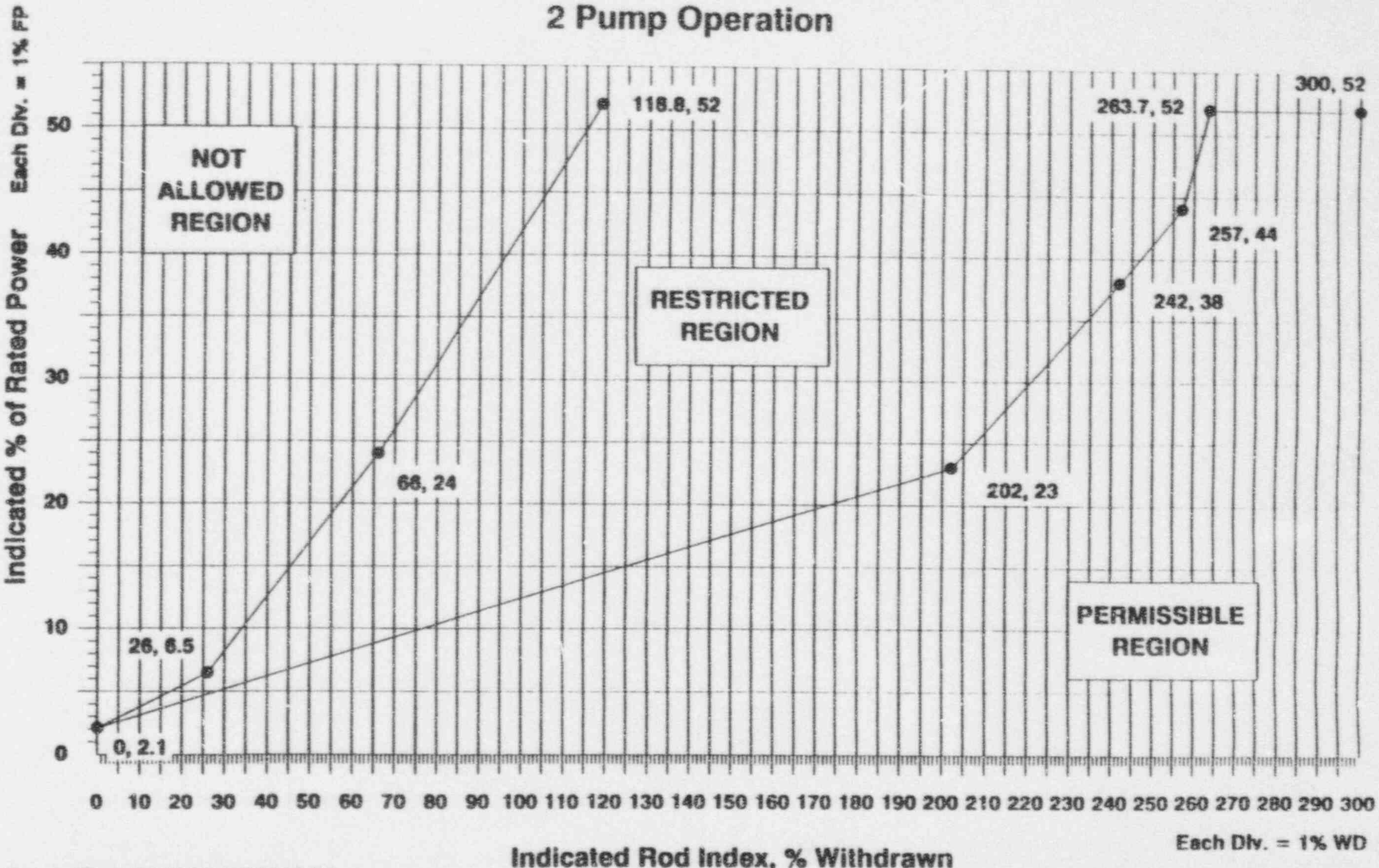
2 Pump Operation



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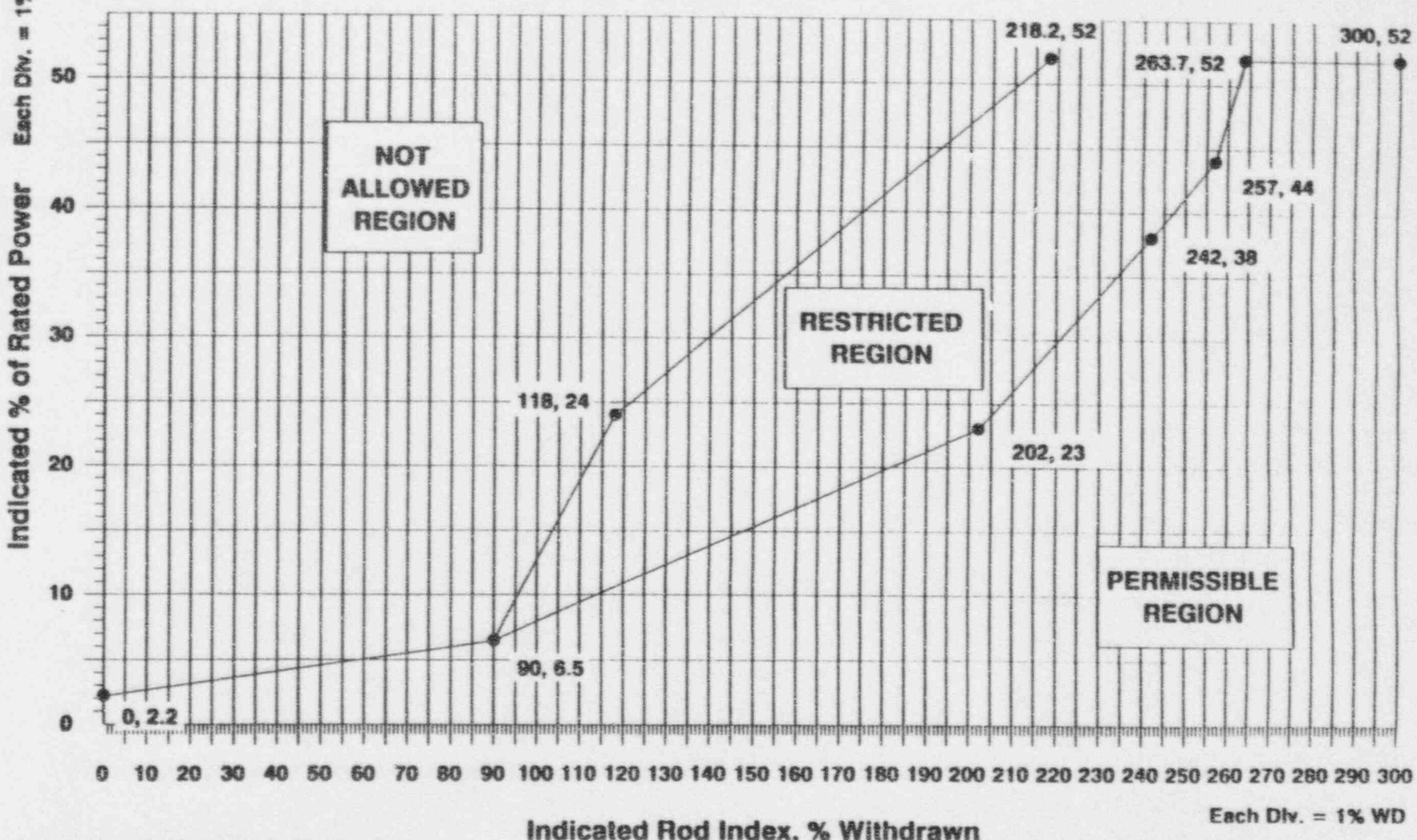
Error Adjusted Rod Insertion Limits
400 +/-10 EFPD to EOC
2 Pump Operation



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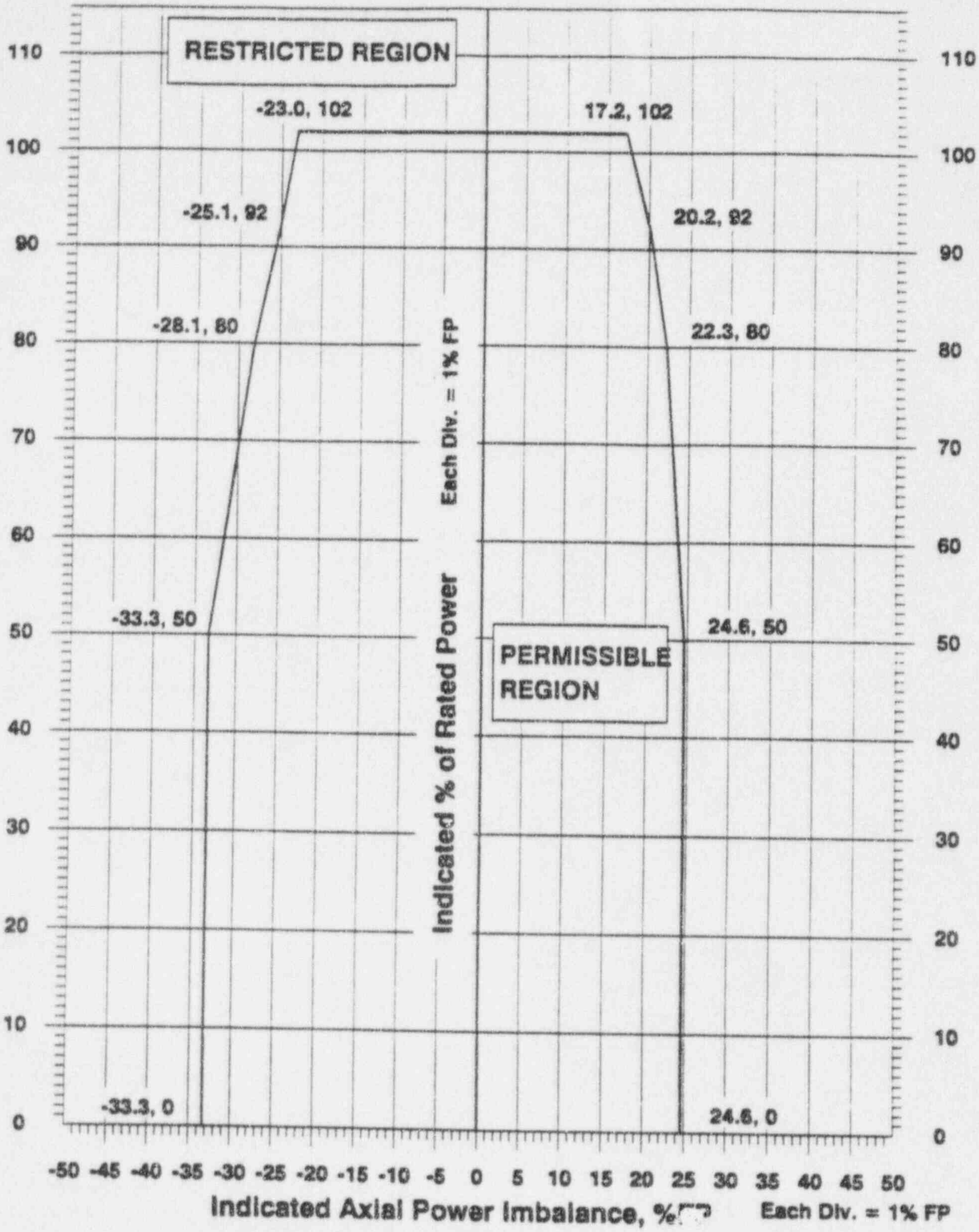
Full Incore System
Error Adjusted Imbalance Limits
0 to 75 +0/-10 EFPD



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Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

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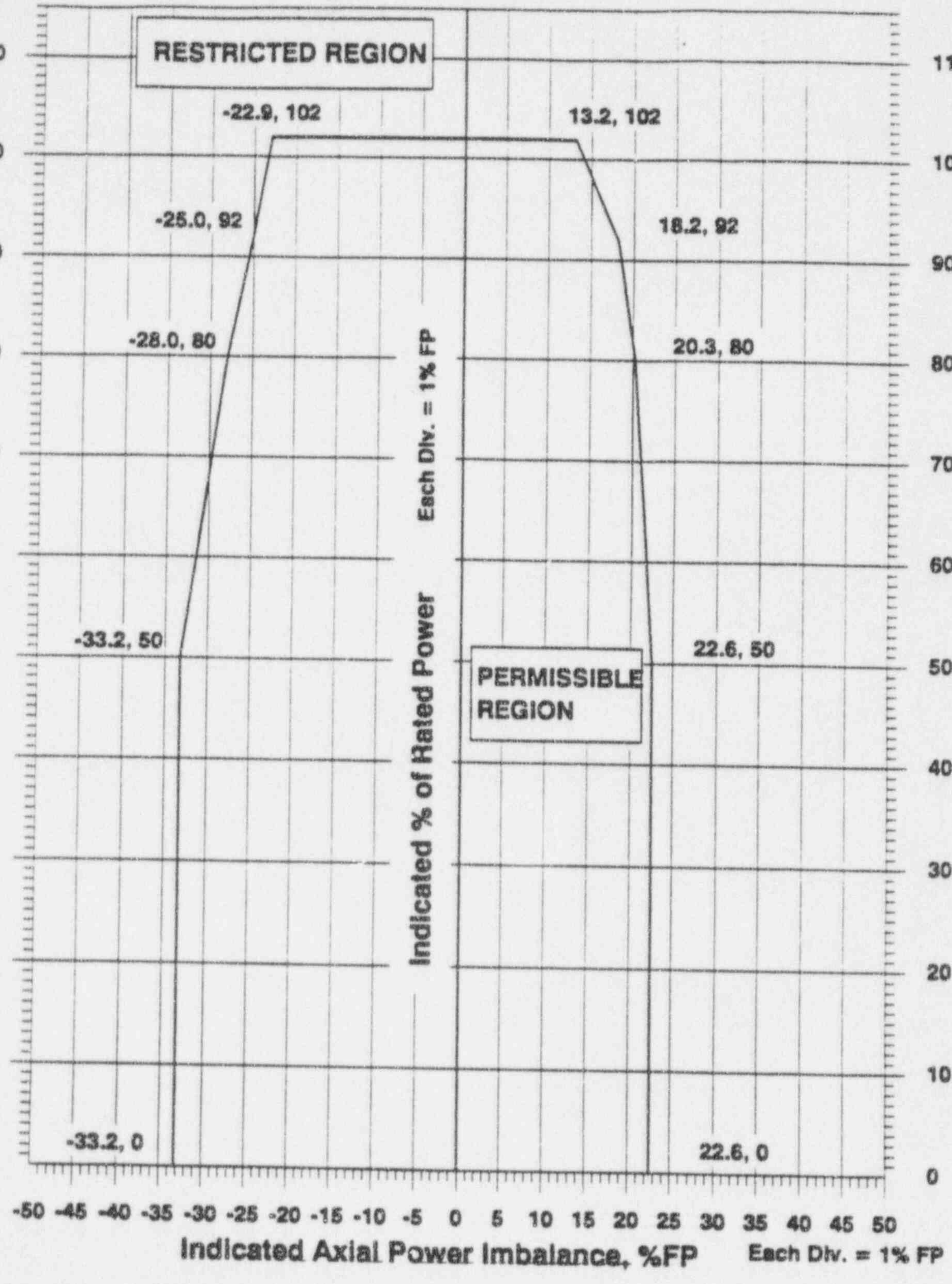
Full Incore System
Error Adjusted Imbalance Limits
75 +0/-10 TO 300 +/- 10 EFPD



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Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

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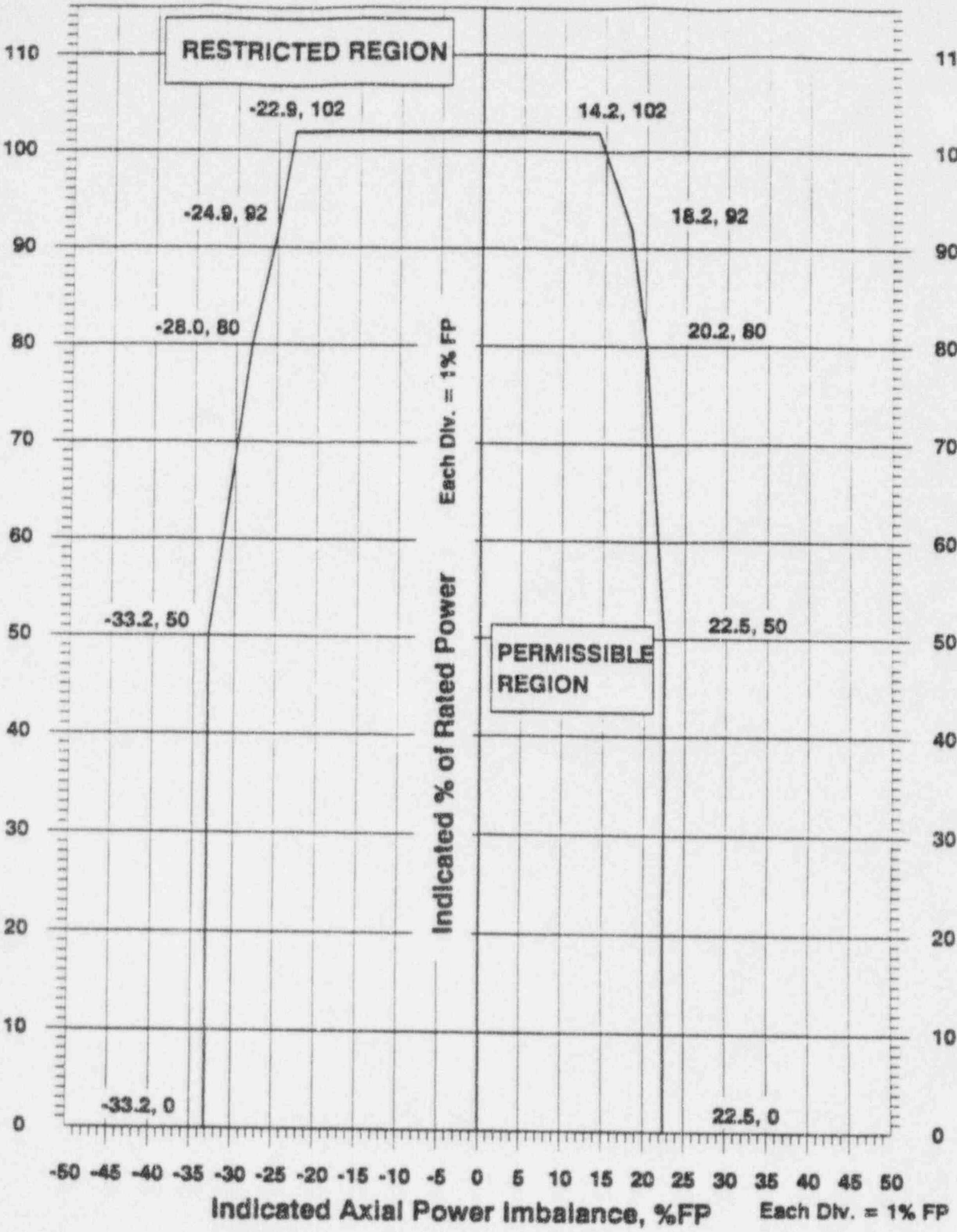

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Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

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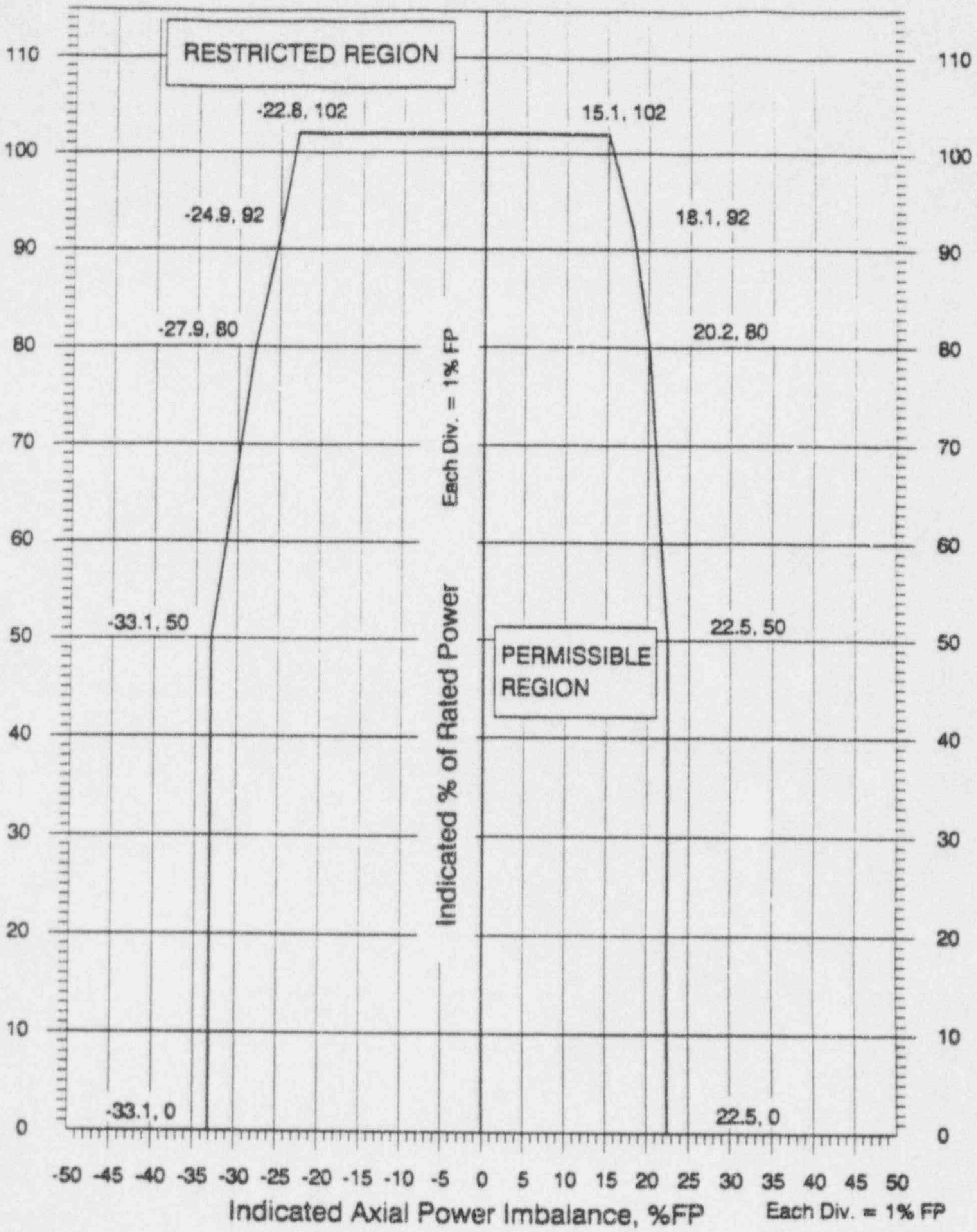

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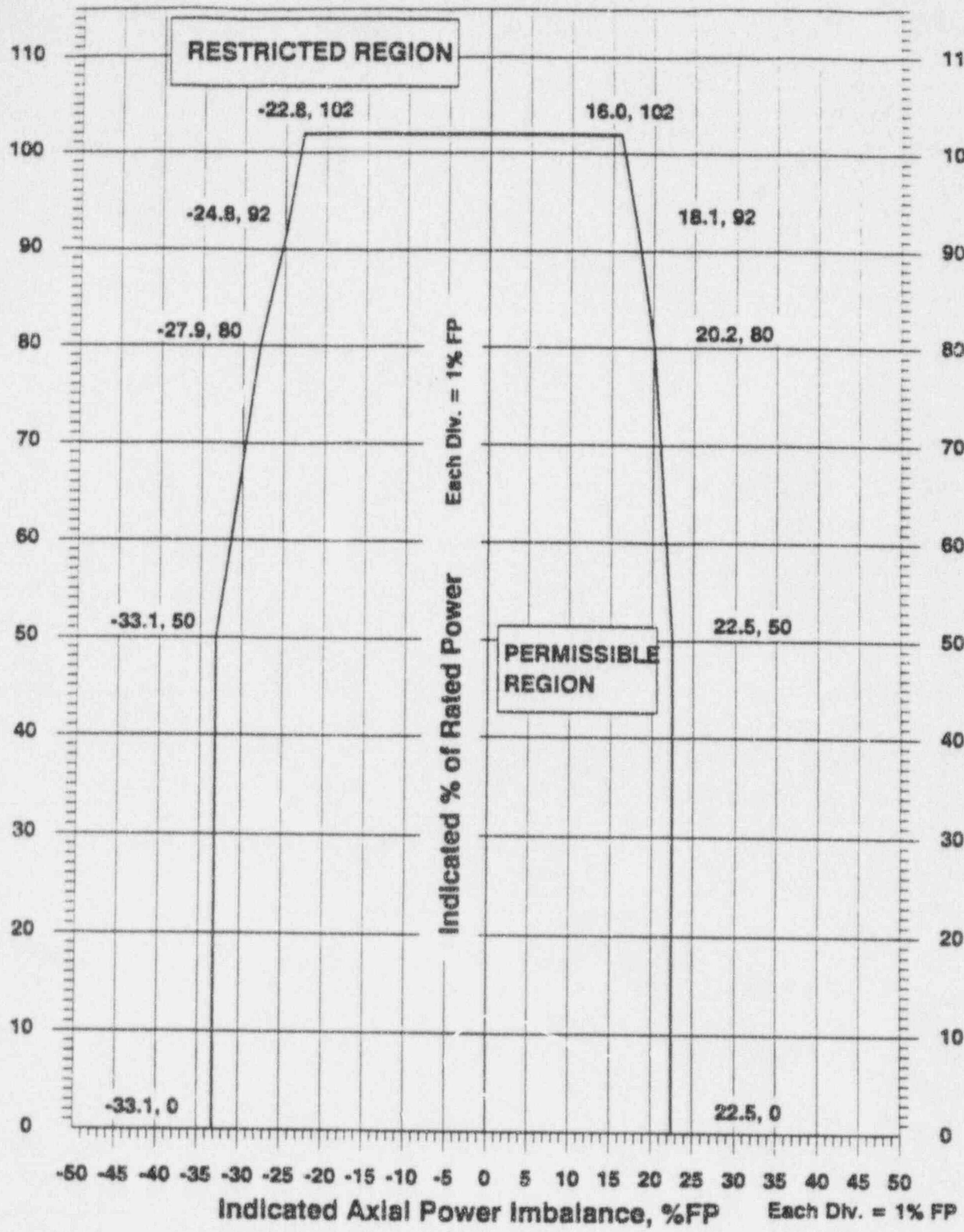

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Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

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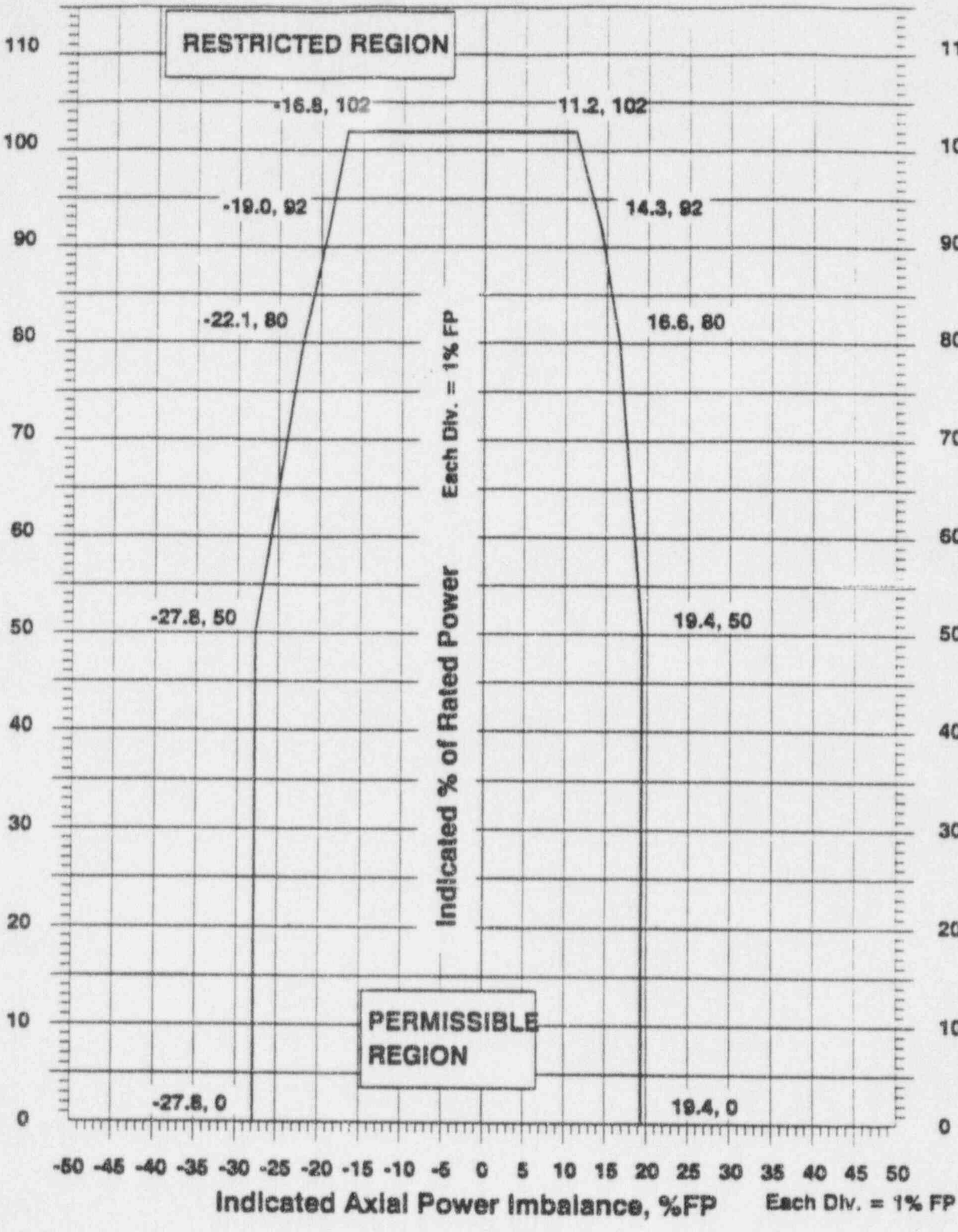
Out-of-Core Detector System
Error Adjusted Imbalance Limits
0 to 75 +0/-10 EFPD



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Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

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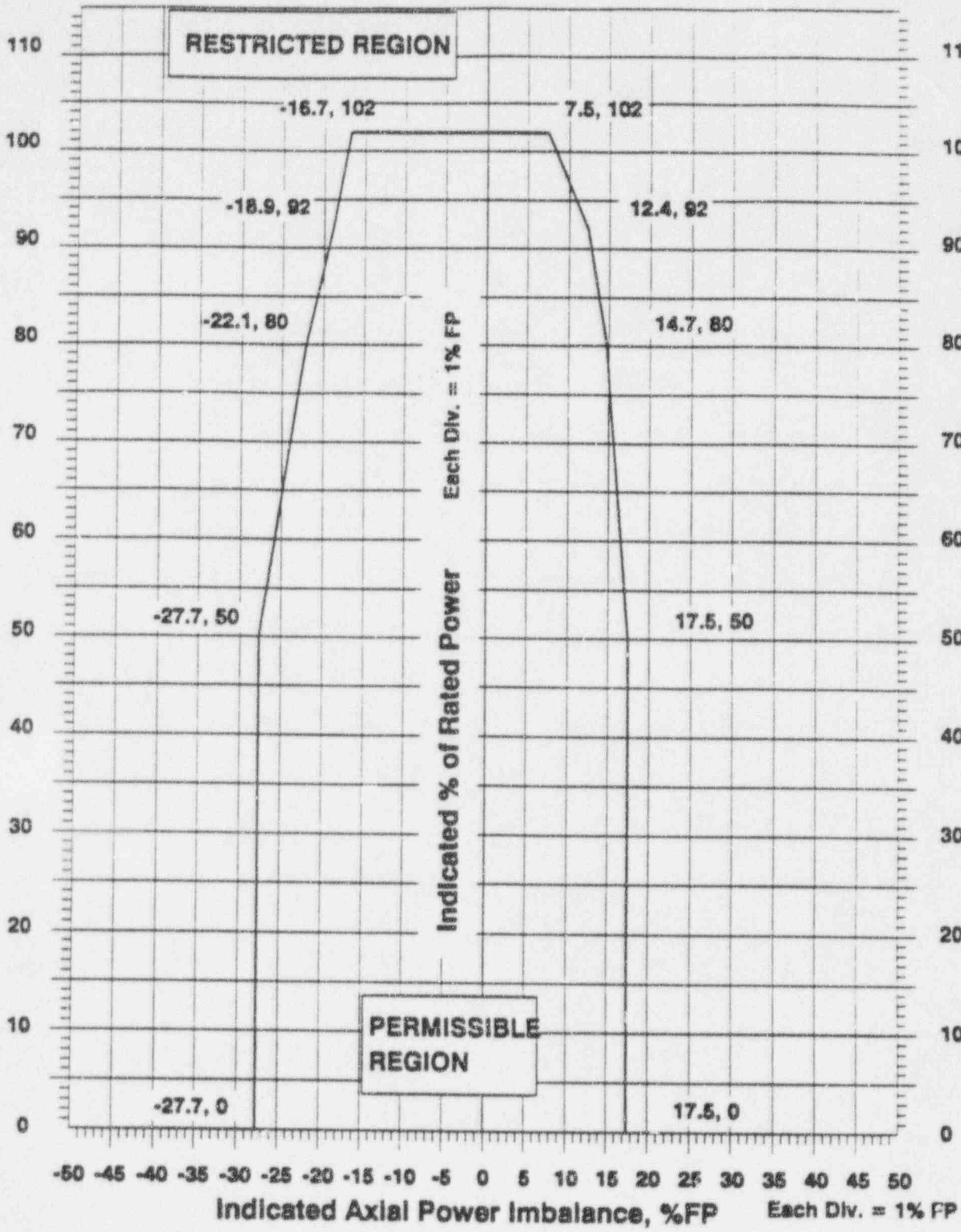
Out-of-Core Detector System
Error Adjusted Imbalance Limits
75 +0/-10 to 300 +/-10 EFPD



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Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

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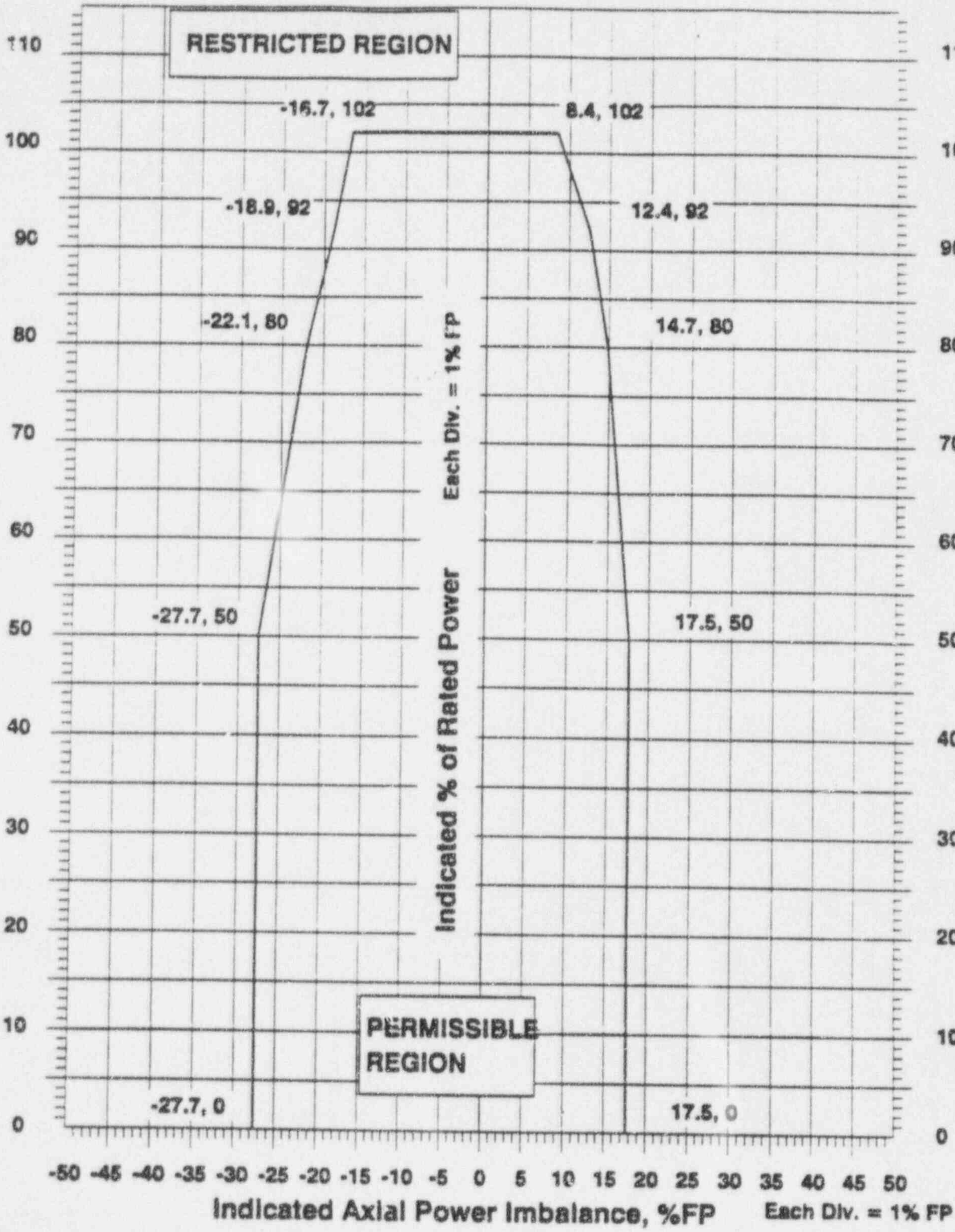
Out-of-Core Detector System
Error Adjusted Imbalance Limits
300 +/-10 to 400 +/-10 EFPD



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Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

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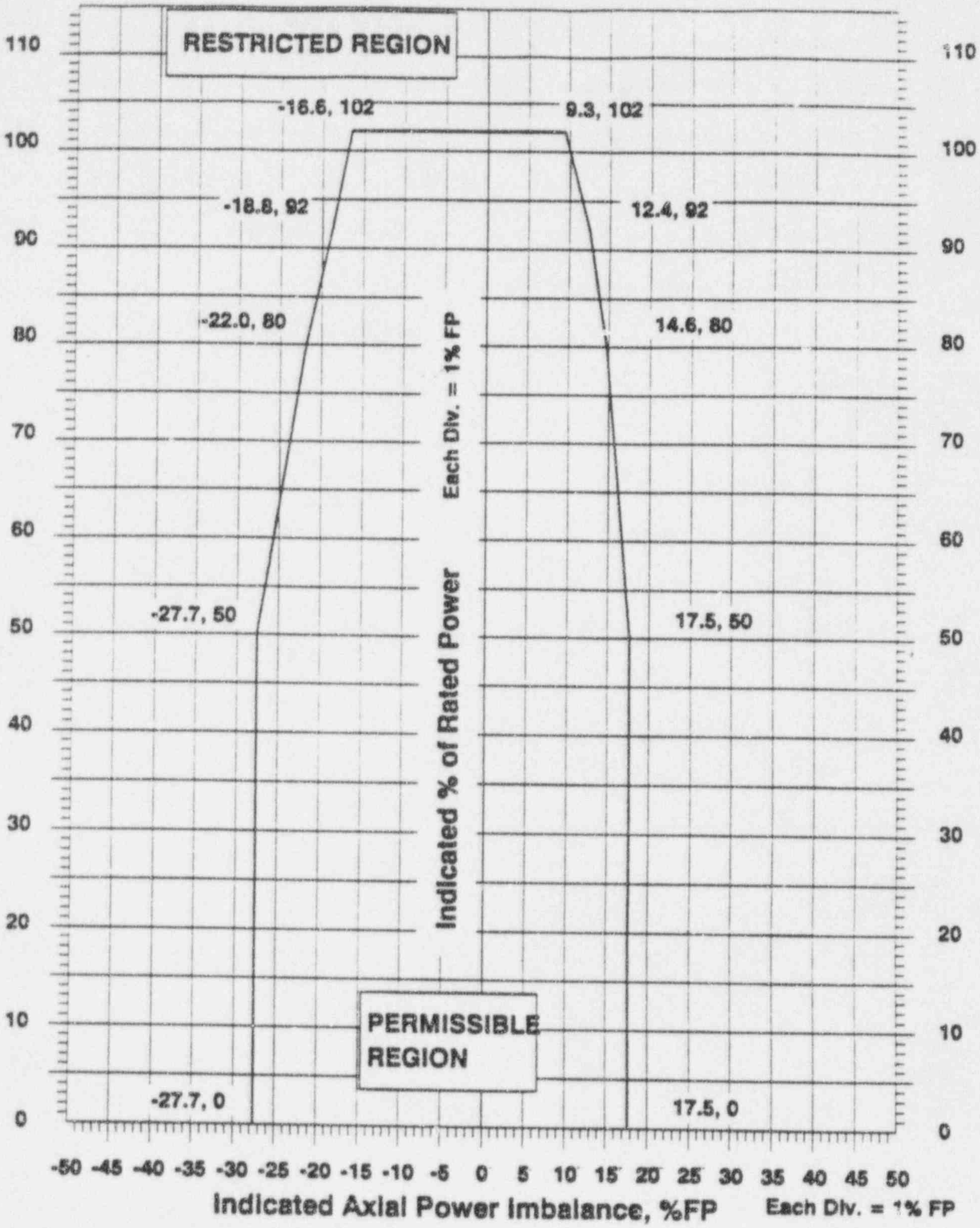
400 +/-10 to 500 +/-10 EFPD



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Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

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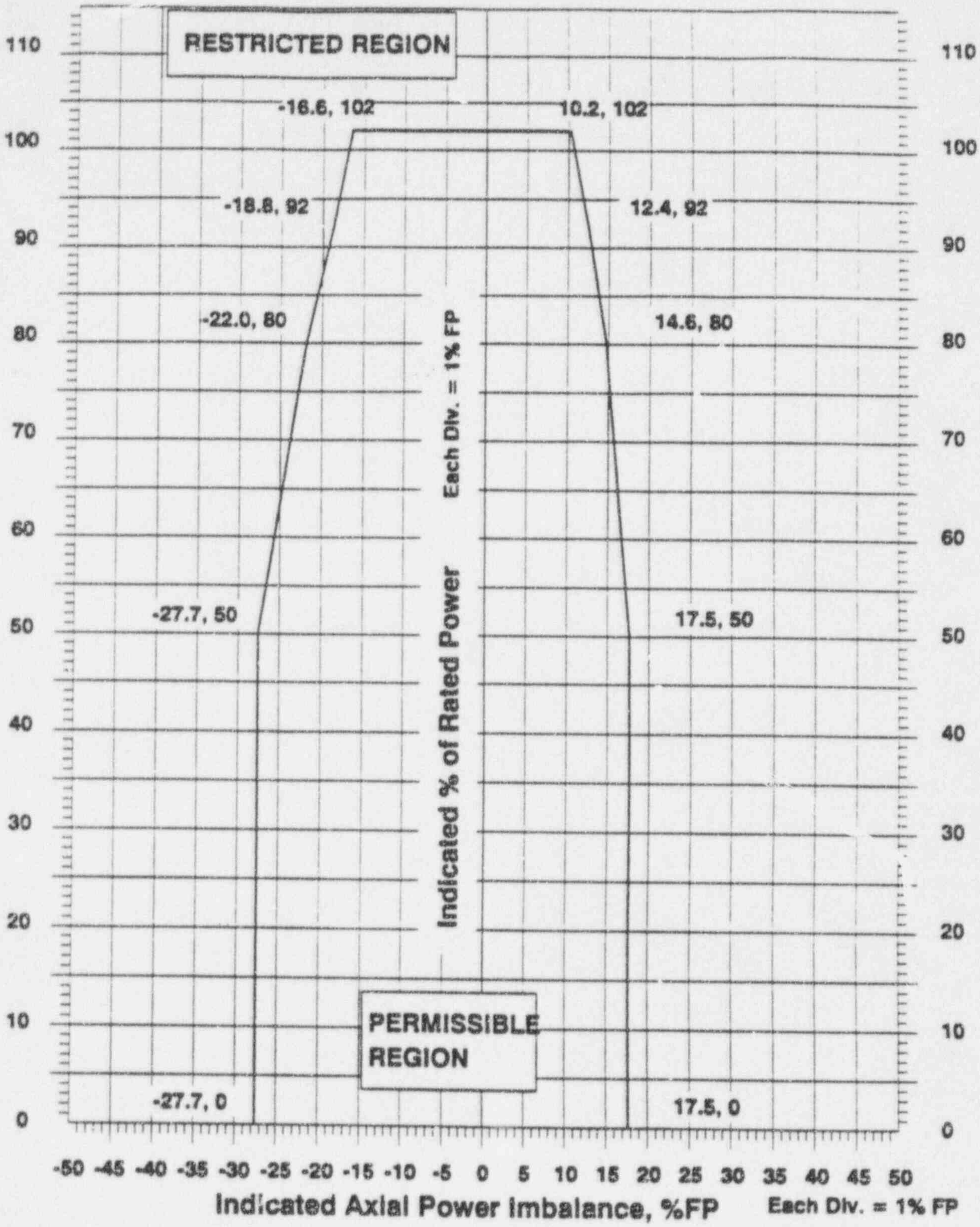
Out-of-Core Detector System
Error Adjusted Imbalance Limits
500 +/-10 EFPD to EOC



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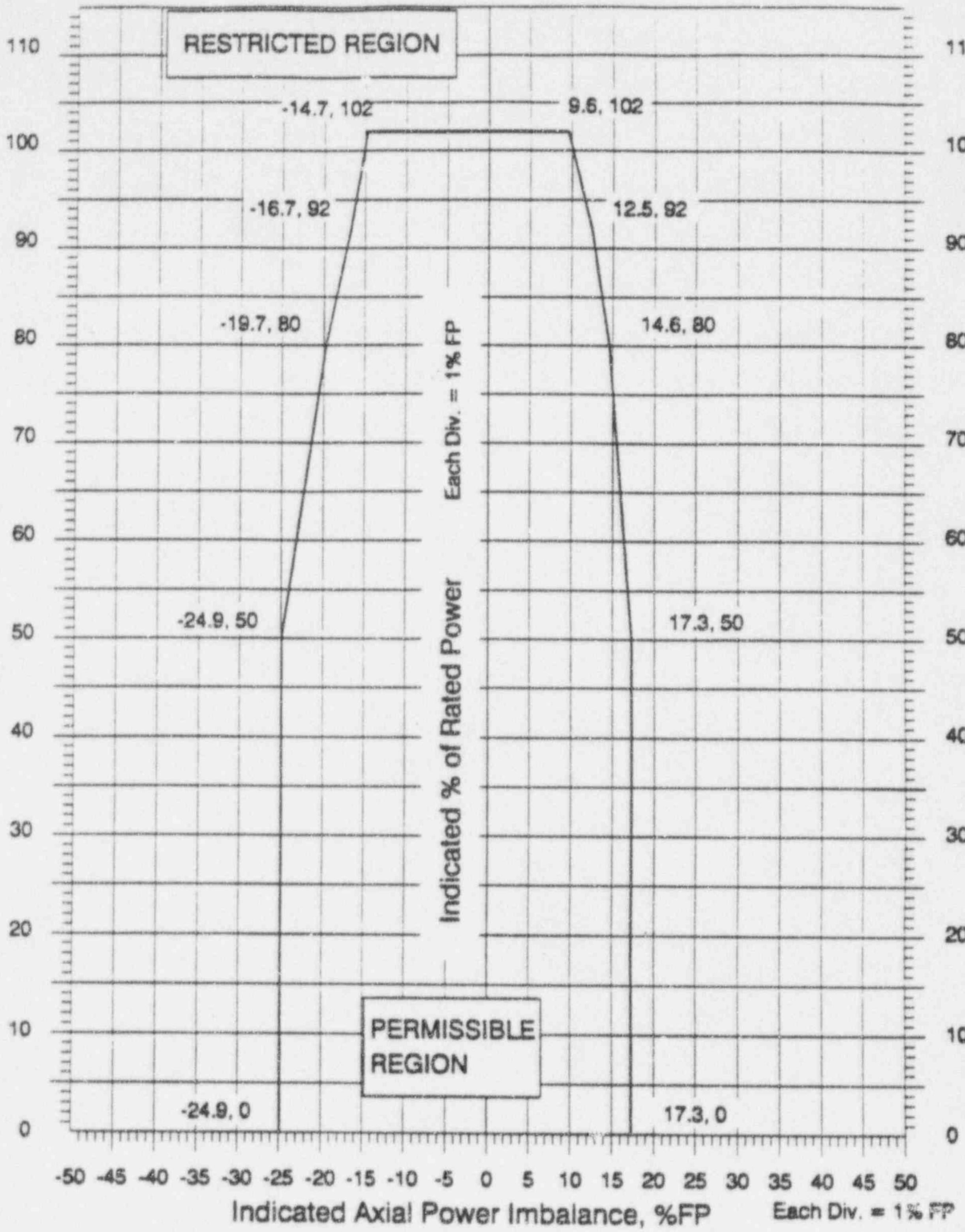
Minimum Incore System
Error Adjusted Imbalance Limits
0 to 75 +0/-10 EFPD



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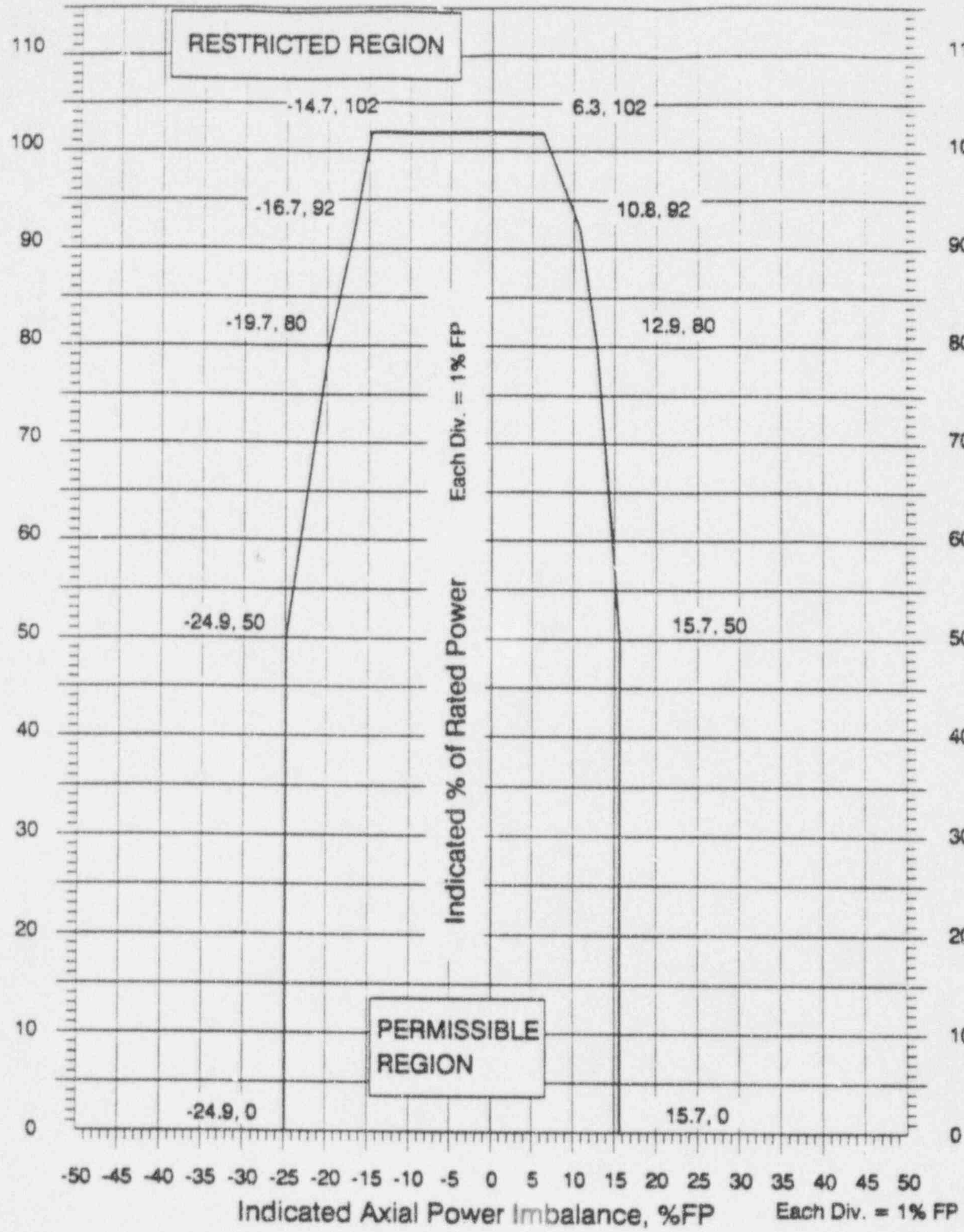
Minimum Incore System
Error Adjusted Imbalance Limits
75 +0/-10 to 300 +/-10 EFPD



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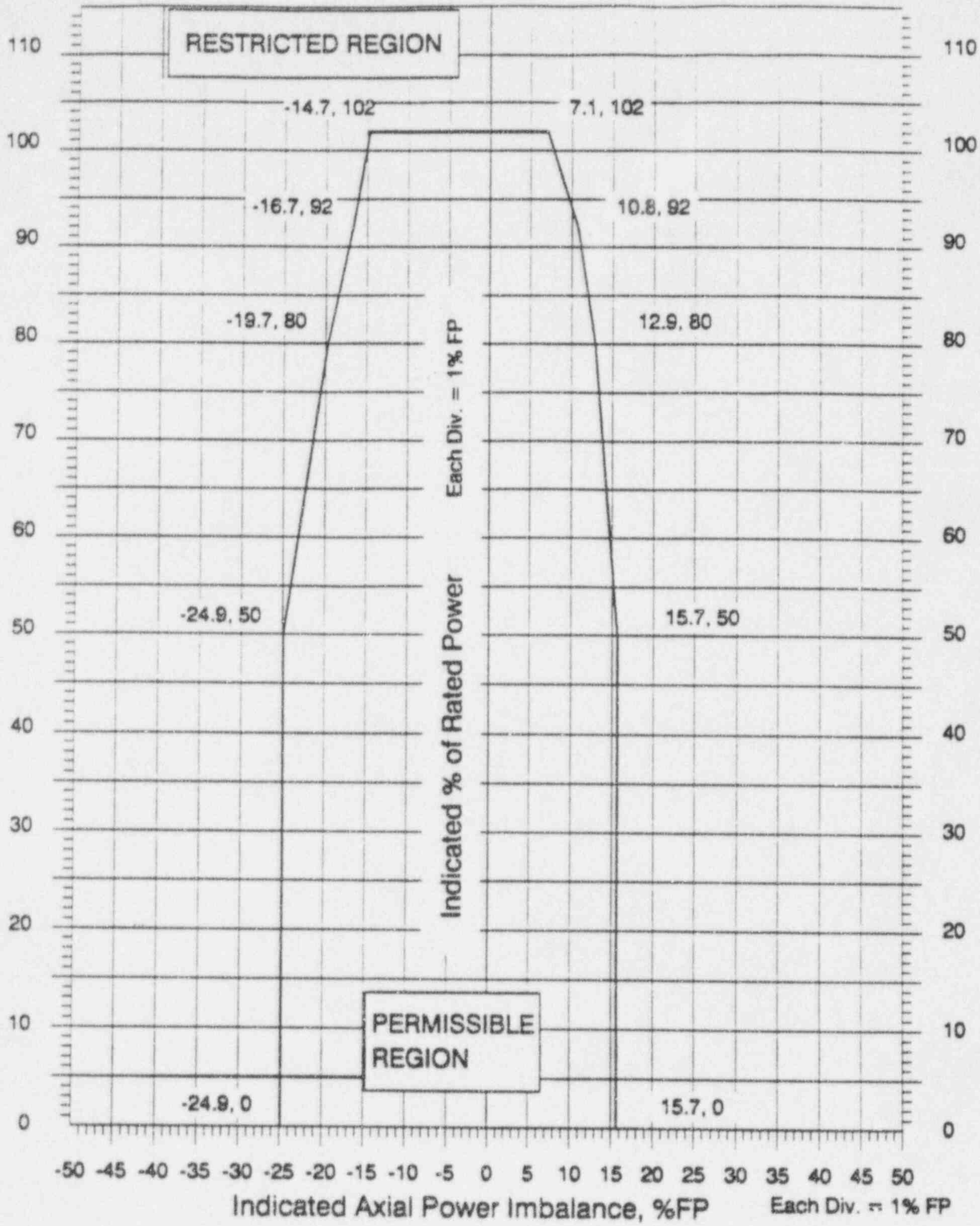
Minimum Incore System
Error Adjusted Imbalance Limits
300 +/-10 to 400 +/-10 EFPD



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Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

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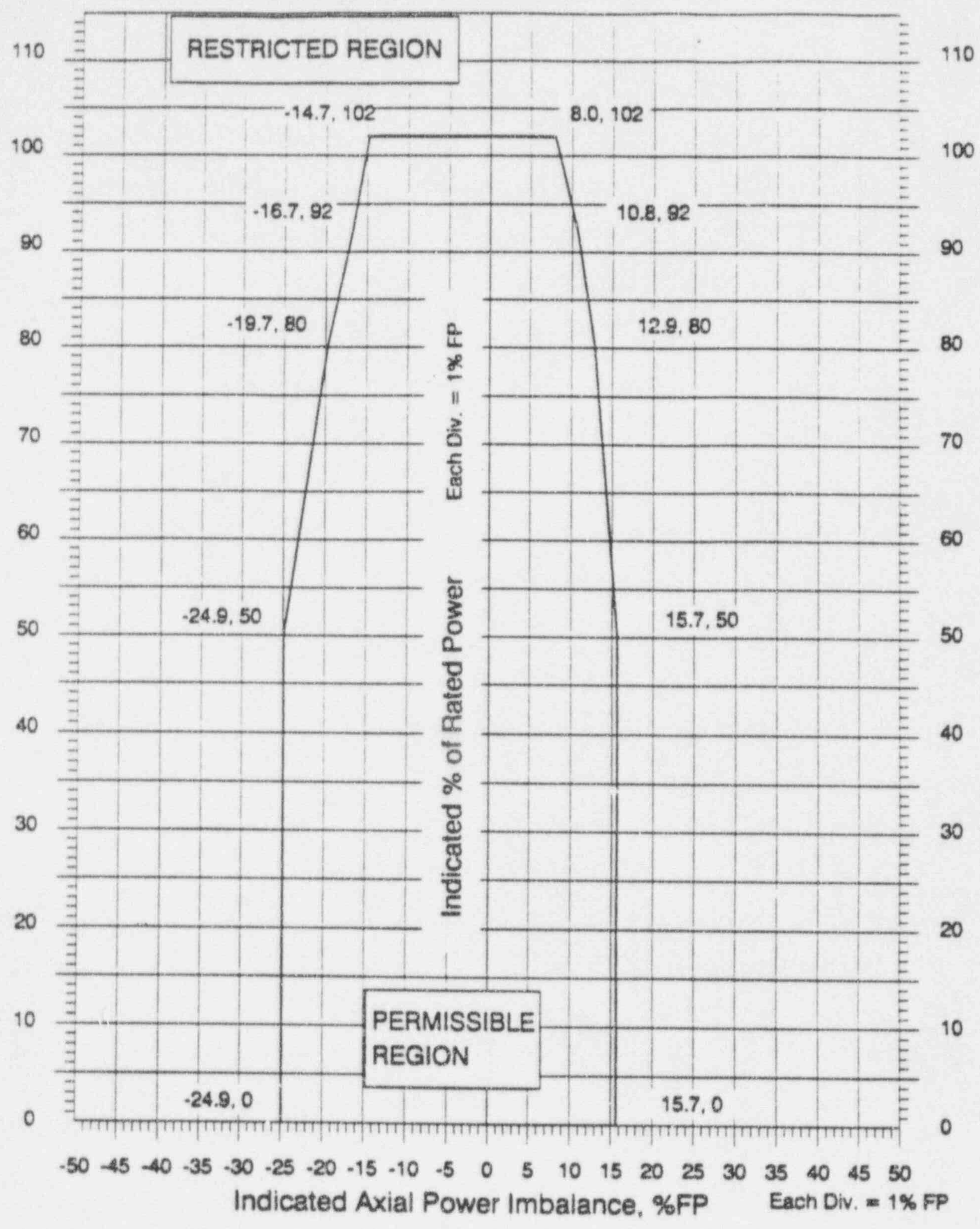
Minimum Incore System
Error Adjusted Imbalance Limits
400 +/-10 to 500 +/-10 EFPD



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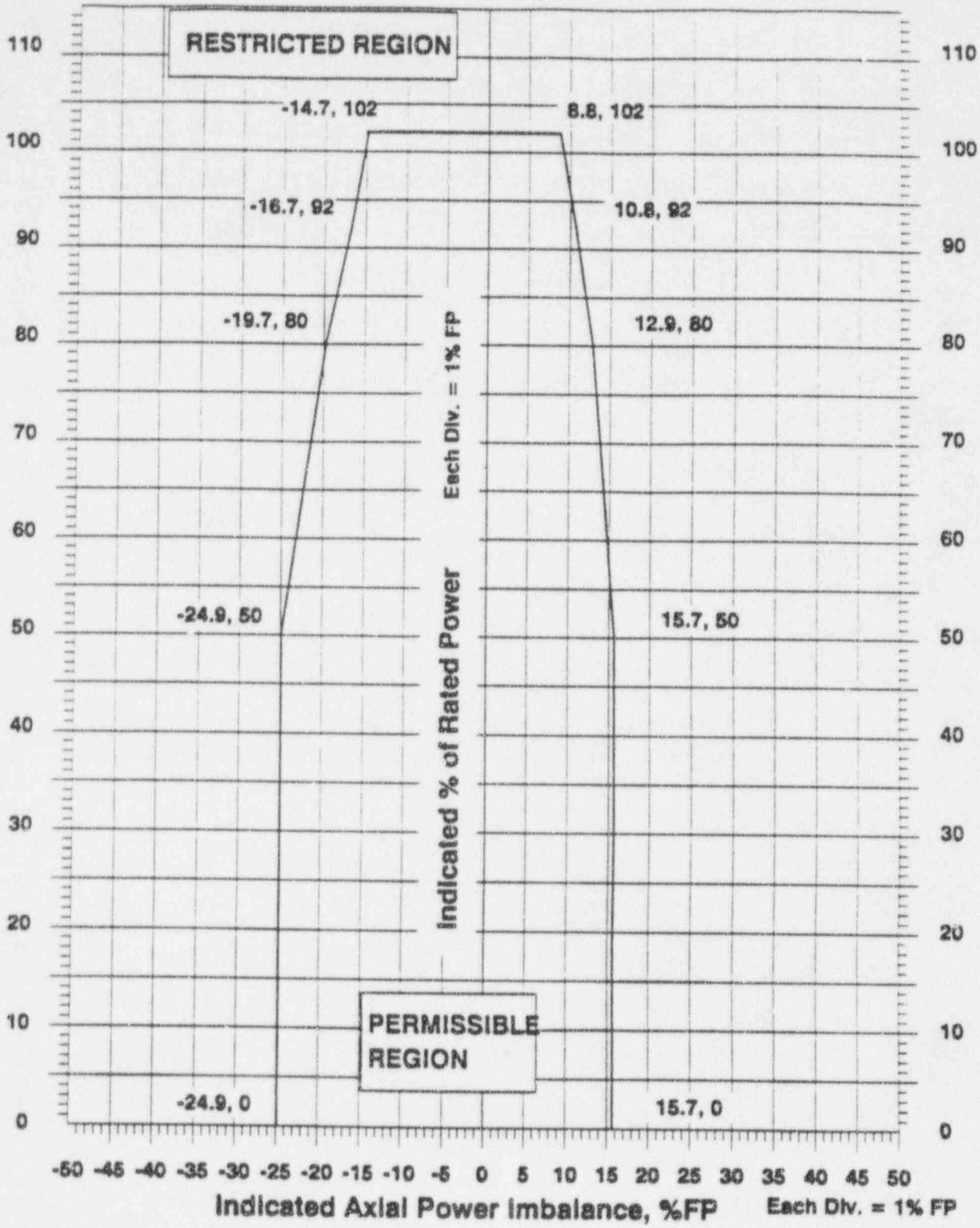
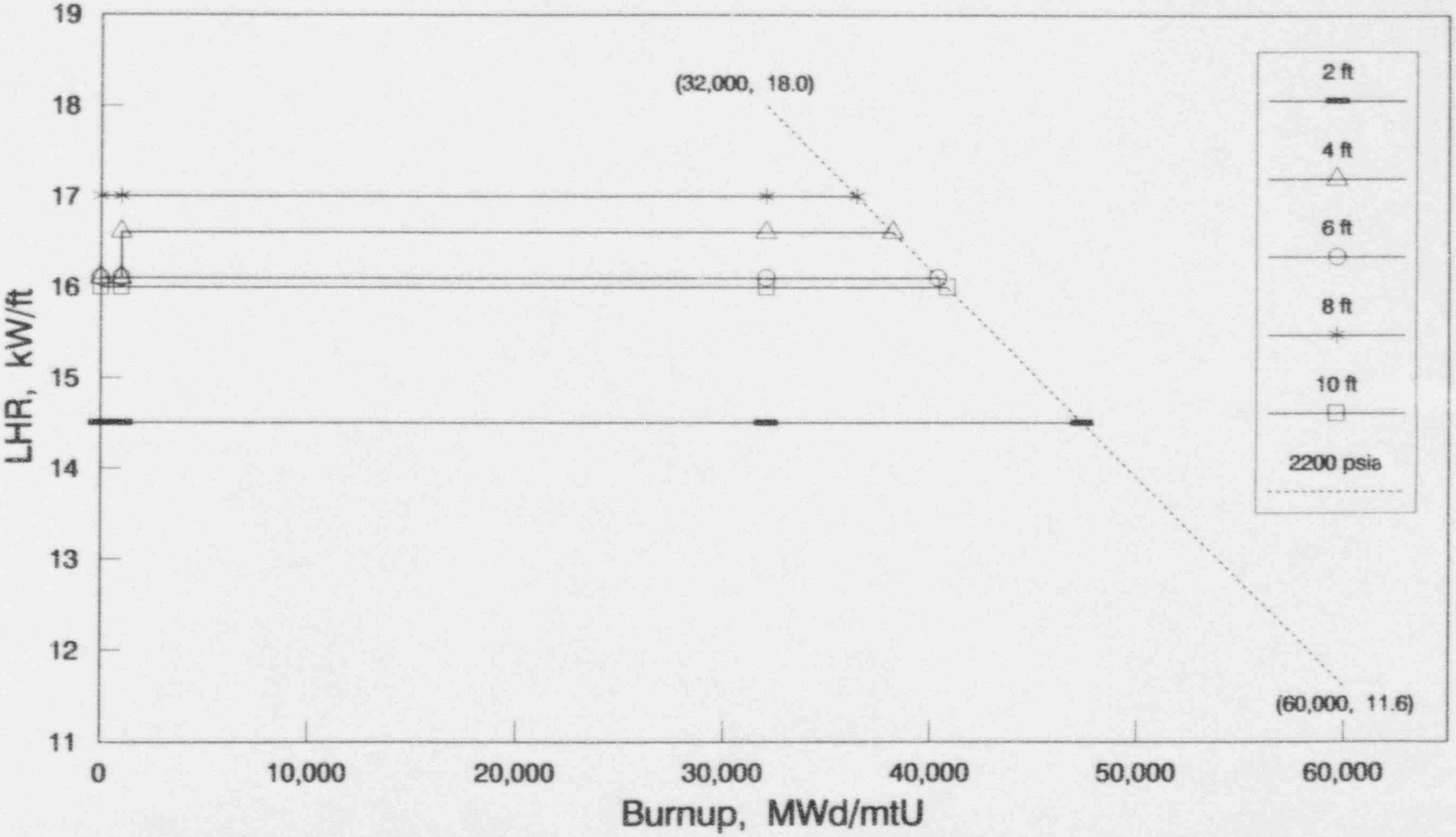
Minimum Incore System
Error Adjusted Imbalance Limits
500 +/-10 EFPD to EOC



Source Doc. B&W 86-1223246-00

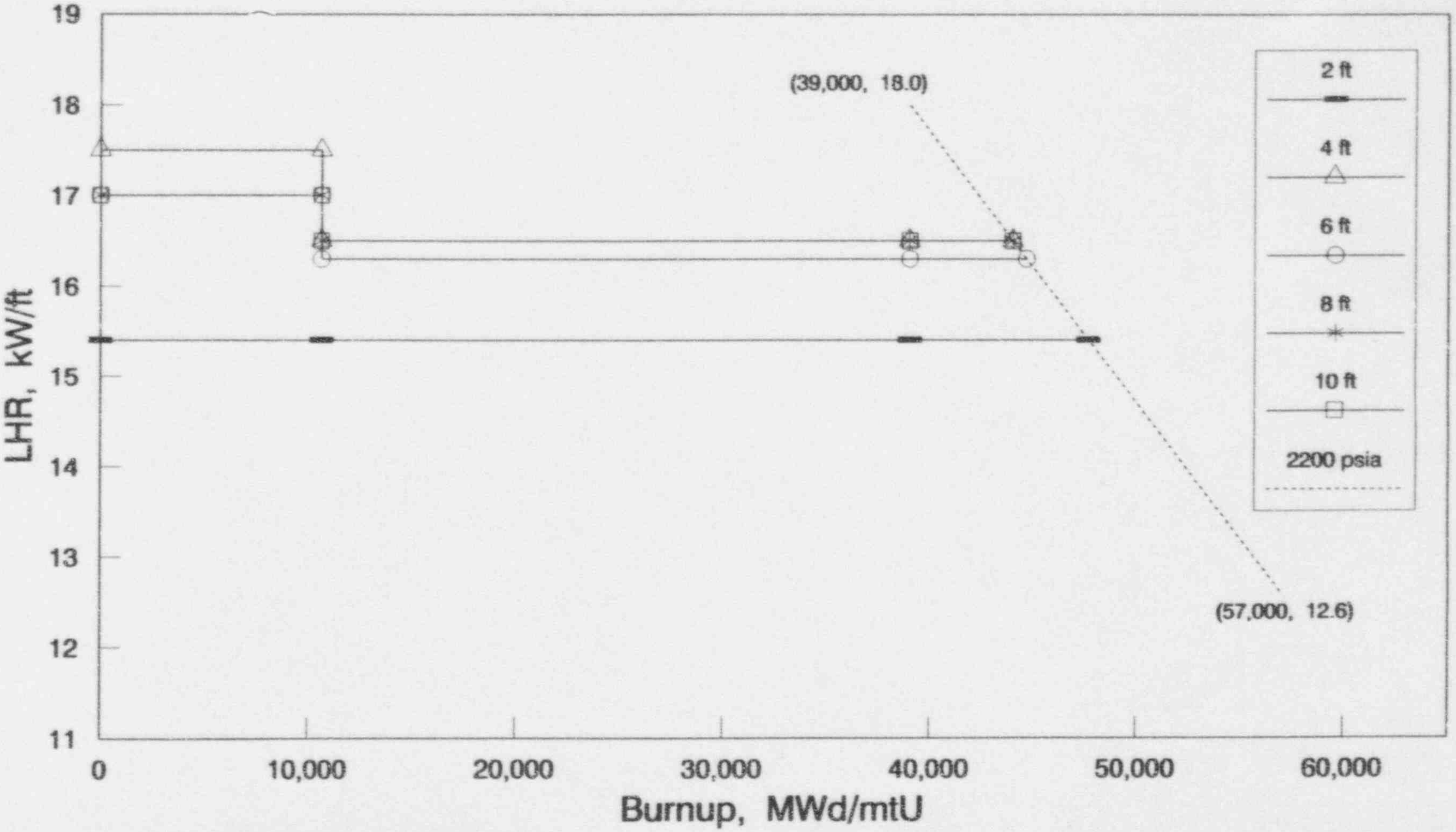
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

FIGURE 7 (Page 1 of 2)
LOCA Limited Maximum Allowable Linear Heat Rate
Mark B8 Fuel



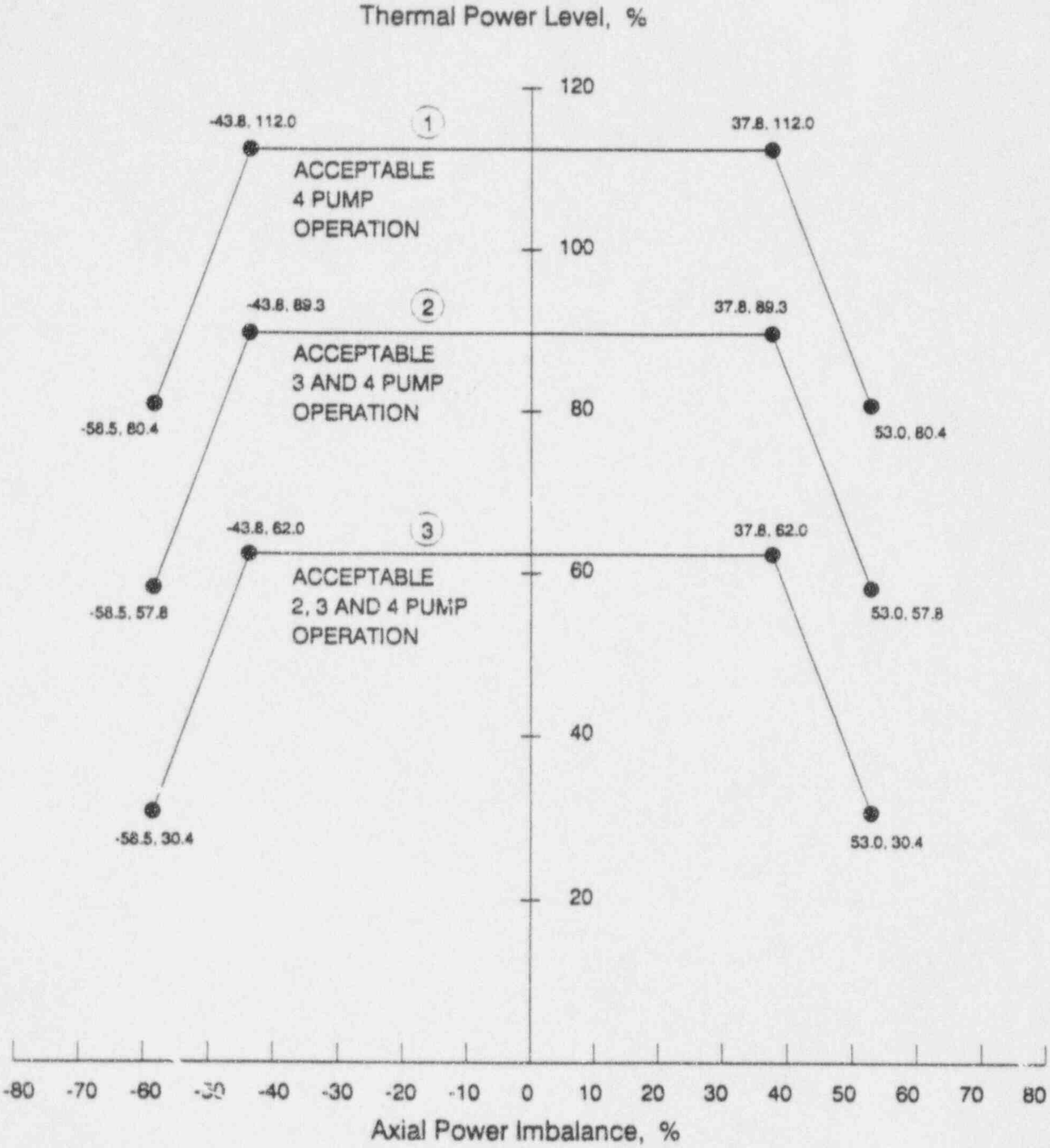
Source Soc. BAW 2187, BWNT Doc. No. 51-1234870-00
Referred to by Tech Spec 3.5.2.8

FIGURE 7 (Page 2 of 2)
LOCA Limited Maximum Allowable Linear Heat Rate
Mark B9 Fuel



Source Soc. BAW 2187, BWNT Doc. No. 51-1234870-00
Referred to by Tech Spec 3.5.2.8

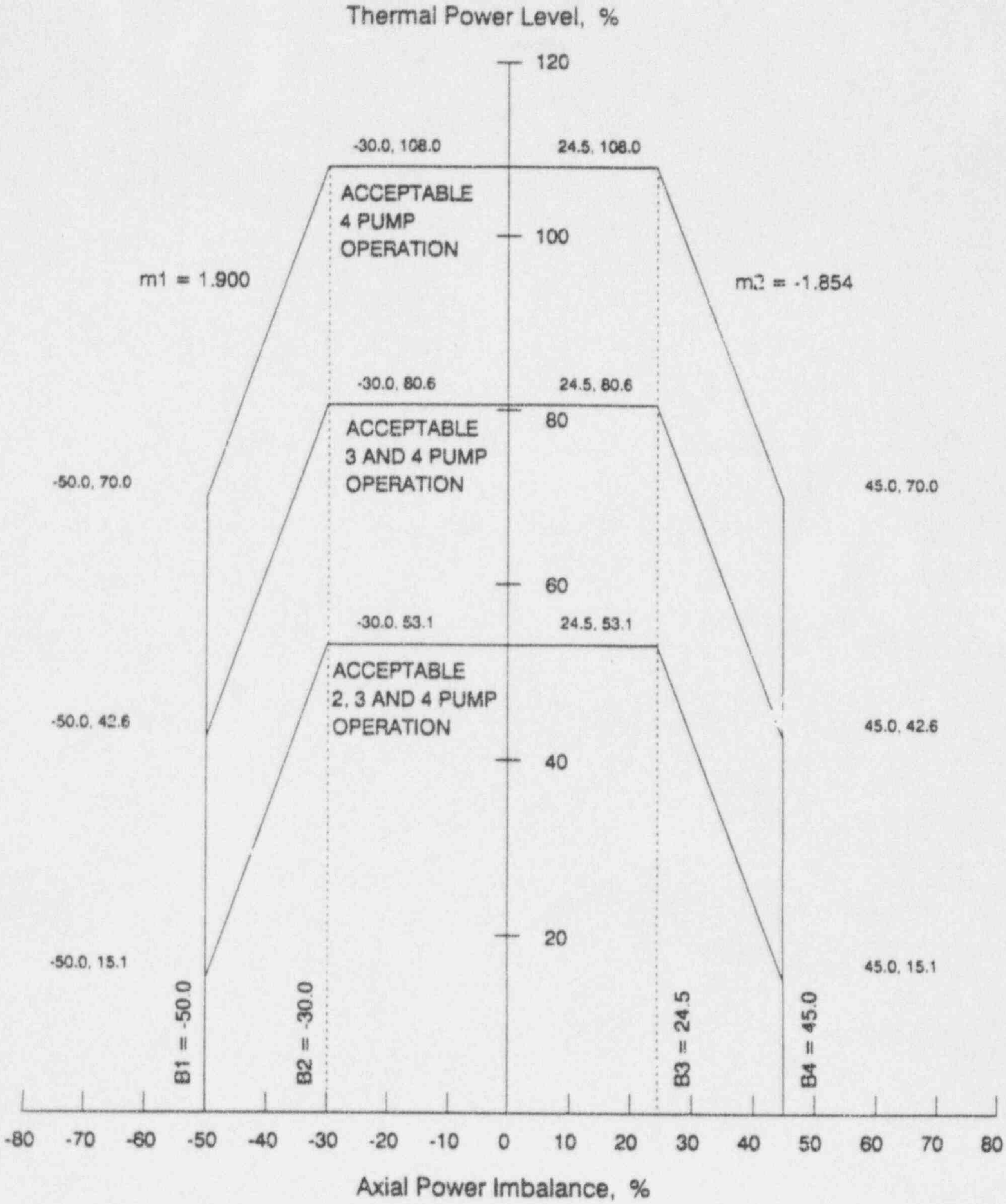
FIGURE 8
AXIAL POWER IMBALANCE PROTECTIVE LIMITS



CURVE	EXPECTED MINIMUM REACTOR COOLANT FLOW (lb/hr)
1	139.8 x 10E+6
2	104.5 x 10E+6
3	68.8 x 10E+6

Source Doc. T.S. Figure 2.1-2

FIGURE 9
PROTECTION SYSTEM MAXIMUM ALLOWABLE SETPOINTS FOR AXIAL POWER IMBALANCE



Source Doc. T.S. Figure 2.3-2

Enclosure 1

Operating Limits Not Required by Technical Specifications

1. Core Minimum DNBR Operating Limit

(Reference: BAW-2187)

The core minimum DNBR value as measured with the NAS Thermal Hydraulic Package (Display 1 or 4) should not be less than 2.02 (102% ICDNBR).

2. Maximum Allowable Local Linear Heat Rate Limits

(Reference: TS 2.1 Bases)

The maximum allowable local linear heat rate limit is the minimum LHR that will cause centerline fuel melt in the rod. This limit is the basis for the imbalance portions of the Axial Power Imbalance Protective Limits and Setpoints in Figures 8 and 9 of the COLR, respectively. The limit is fuel design-specific; the value for the most limiting fuel design in the current core is used for monitoring as given below:

- **<u>BWFC Mark B8/B8V</u>**
  LHR to melt = 20.5 kw/ft

Enclosure 2

DNBR-Related Bases Descriptions

1. <u>Power-to-Flow Trip Setpoint</u>

Reference: TS 2.3.1, Table 2.3-1 and 2.3.1 Bases

The nuclear overpower trip setpoint based on RCS flow (power/flow or flux/flow trip) for the current cycle is 1.08. This setpoint applies to four-, three-and two-pump operation as described in TS Table 2.3-1 and Figure 9 of the COLR.

The power/flow trip, in combination with the axial power imbalance trip, provides steady-state DNB protection for the Axial Power Imbalance Protective Limit (Figure 8). A reactor trip is initiated when the core power, axial power peaking and reactor coolant flow conditions indicate an approach to the DNBR limit. The power/flow trip also provides transient protection for loss of reactor coolant flow events, such as loss of one RC pump from a four RC pump operating condition.

Power level and reactor flow rate combinations for four-, three- and two-pump operating conditions are as follows:

1. Trip would occur when four reactor coolant pumps are operating if power level is 108 percent and flow rate is 100 percent, or power level is 100 percent and flow rate is 92.5 percent.

2. Trip would occur when three reactor coolant pumps are operating if power level is 80.6 percent and flow rate is 74.7 percent or power level is 75 percent and flow rate is 69.4 percent.

3. Trip would occur when one reactor coolant pump is operating in each loop (total of two pumps operating) if power level is 53.1 percent and flow rate is 49.2 percent or power level is 49 percent and flow rate is 45.3 percent.

The power level trip and associated reactor power/axial power-imbalance boundaries are reduced by the power-to-flow ratio as a percent (1.08 percent) for each one percent flow reduction.

2. Design Nuclear Power Peaking Factors (Reference: TS 2.1 Bases)

The design nuclear power peaking factors given below define the reference design peaking condition in the core for operation at the maximum overpower. These peaking factors serve as the basis for the pressure/temperature core protection safety limits and the power-to-flow limit that prevent cladding failure due to DNB overheating.

- Nuclear Enthalpy Rise Hot Channel Factor (Radial-Local Peaking Factor), $F^N_{\Delta H}$

  $F^N_{\Delta H} = 1.71$

- Axial Flux Shape Peaking Factor, F^N_z

  $F^N_z = 1.65$ (cosine)

- Total Nuclear Power Peaking Factor, F^N_q

  $F^N_q = F^N_{\Delta H} \times F^N_z$

  $F^N_q = 2.82$