TMI-1 Cycle 11
Core Operating Limits Report

TOPICAL REPORT 101
Rev. 0

BA Number 135400

TMI-1 Cycle 11 Reload Task Force
October, 1995

APPROVALS;

Robert Jaffe 10-10-95
Originator Date

10/10/95
Cycle 11 Reload Task Force Chairman Date

10/10/95
Manager, TMI Fuel Projects Date

G. R. Bond 10-10-95
Director, Nuclear Analysis & Fuel Date

10/11/95 10/11/95
Plant Review Group Date

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 1 through 7 and were documented in References 8 through 10. The information in this COLR was reviewed for use at TMI-1 in References 11 through 14.

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.

The minimum boron volumes and concentrations for the Borated Water Storage Tank (BWST), Boric Acid Mix Tank (BAMT) and Reclaimed Boric Acid Storage Tanks (RBAST) contained in Table 3 will ensure that enough boron is available to achieve cold shutdown conditions.

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 fuel batch, 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:

1. BAW-10179P-A, Rev. 0, "Safety Criteria and Methodology for Acceptable Cycle Reload Analyses," August 1993.

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

3. BAW-10183P, "Fuel Rod Gas Pressure Criterion (FRGPC)," July 1991.

4. BAW-2149-A, "Evaluation of Replacement Rods in BWFC Fuel Assemblies," September 1993.

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

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

7. BAW-10156-A, Rev. 1, "LYNXT Core Transient Thermal-Hydraulic Program," Auigust 1993.

8. BAW-2250, Rev. 1, "TMI-1 Cycle 11 Reload Report," September 1995.

9. BWFC Doc. No. 51-1236516-01, "TMI-1 Cycle 11 COLR LOCA Limits," October 9, 1995.

10. BWFC Doc. No. 51-1240294-00, "TMI-1 Cycle 11 Verification Report," October 1995.

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

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

13. GPUN Safety Evaluation 135400-019, Rev. 1, "Removal of Axial Power Imbalance Protective Limits and Setpoints from TS to COLR," May 8, 1995.

14. GPUN Safety Evaluation 135400-022, Rev. 1, "TMI-1 Cycle 11 Reload Design," October 1995.

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)	6.79%	3.81%	16.8%
Out-of-Core Detector System (OCD)	4.05%	1.96%	14.2%
Minimum Incore System (MIS)	2.80%	1.90%	9.5%

Note: MIS limits assume no MIS detectors exceed 60% sensitivity depletion.

Source Doc.: B&W 86-1235288-00
Referred to by: Tech Spec. 3.5.2.4

TABLE 2 (Page 1 of 2)

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

Batches 10E, 11D and 11E

CMS Level	0 - 665 EFPD
8	8.9
7	10.6
6	11.2
5	11.2
4	11.2
3	11.2
2	10.6
1	8.9

Batches 12B, 12C, 12D and 12E

CMS Level	0 - 7 EFPD	7 - 278 EFPD	278 - 387 EFPD	387 - 433 EFPD	433 - 665 EFPD
8	13.2	13.2	12.9	12.4	9.9
7	15.7	15.7	15.4	14.7	11.8
6	16.4	16.4	16.1	15.5	12.4
5	16.3	16.3	16.0	15.5	12.4
4	16.3	16.3	16.0	15.5	12.4
3	15.7	16.1	15.8	15.5	12.4
2	14.6	15.1	14.8	14.6	11.7
1	12.4	12.8	12.5	12.4	9.9

Batch 13A

CMS Level	0 - 58 EFPD	58 - 321 EFPD	321 - 665 EFPD
8	12.8	12.8	12.8
7	15.2	15.2	15.2
6	16.2	16.2	16.2
5	16.1	16.1	16.1
4	16.1	16.1	16.1
3	15.1	15.2	15.7
2	14.0	14.0	14.7
1	11.8	11.8	12.4

TABLE 2 (Page 2 of 2)

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

Batches 13B, 13C, 13D and 13E

CMS Level	0 - 241 EFPD	241 - 375 EFPD	375 - 665 EFPD
8	13.6	13.2	13.2
7	16.2	15.7	15.7
6	17.0	16.4	16.4
5	17.0	16.3	16.3
4	17.0	16.3	16.3
3	16.0	15.7	16.1
2	14.6	14.6	15.1
1	12.4	12.4	12.8

Batches 13F and 13G

CMS Level	0 - 244 EFPD	244 - 665 EFPD
8	13.6	13.2
7	16.2	15.7
6	17.0	16.4
5	17.0	16.3
4	17.0	16.3
3	16.0	15.7
2	14.6	14.6
1	12.4	12.4

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 Doc. B&W 51-1236516-00

TABLE 3

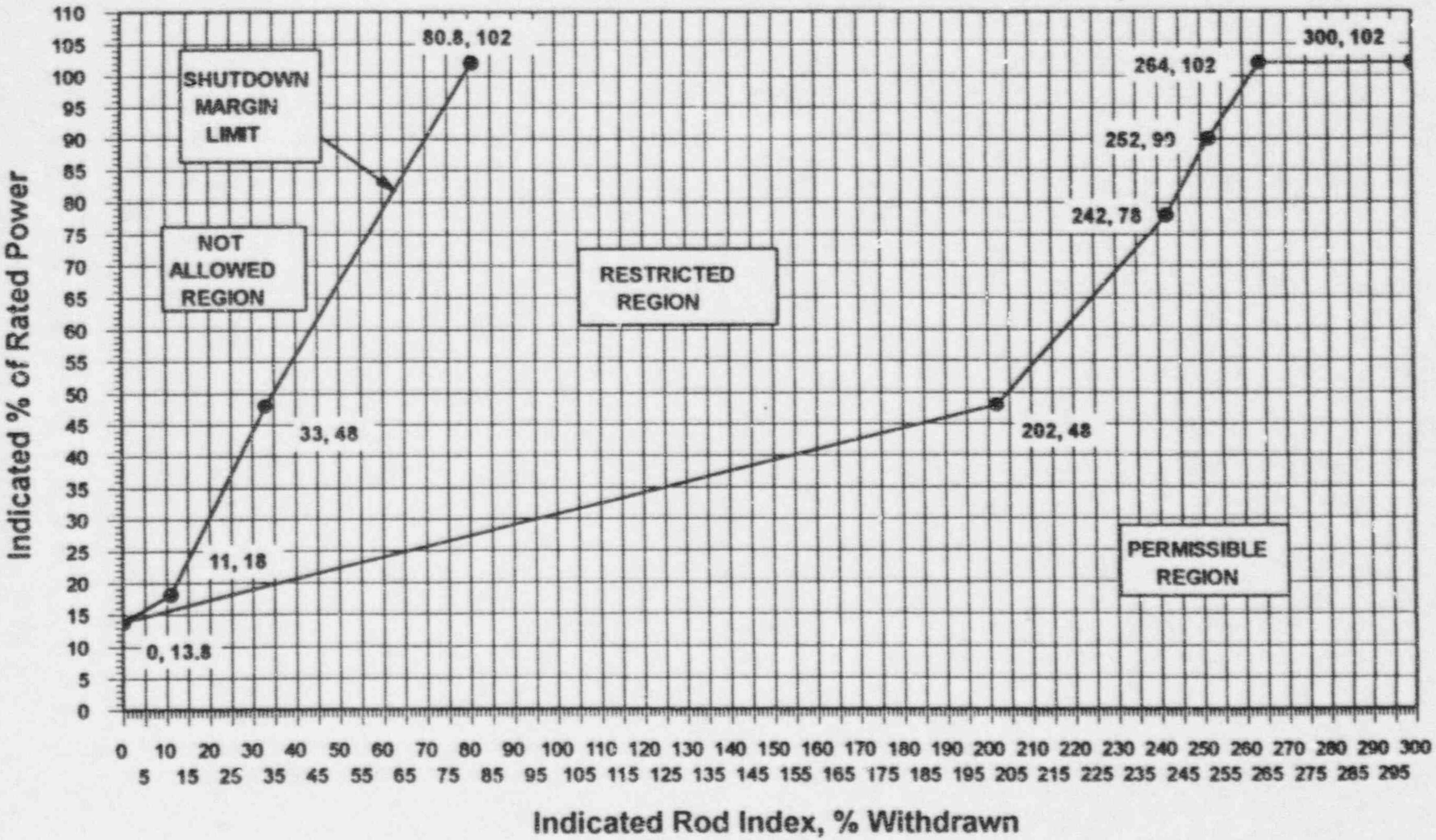
BWST, BAMT and RBAST
Minimum Boron Requirements for Cold Shutdown

1. **The minimum boron requirement for the BAMT and RBASTs is the equivalent of at least 1052 ft.^{3} of 8,700 ppm boron.**

2. **The minimum boron requirement for the BWST is the equivalent of at least 38,604 gallons of 2,500 ppm boron.**

NOTE: The basis for the above BWST minimum boron requirement is to achieve cold shutdown conditions only. This requirement is bounded by the BWST ECCS requirement of T.S. 3.3.1.1.a.

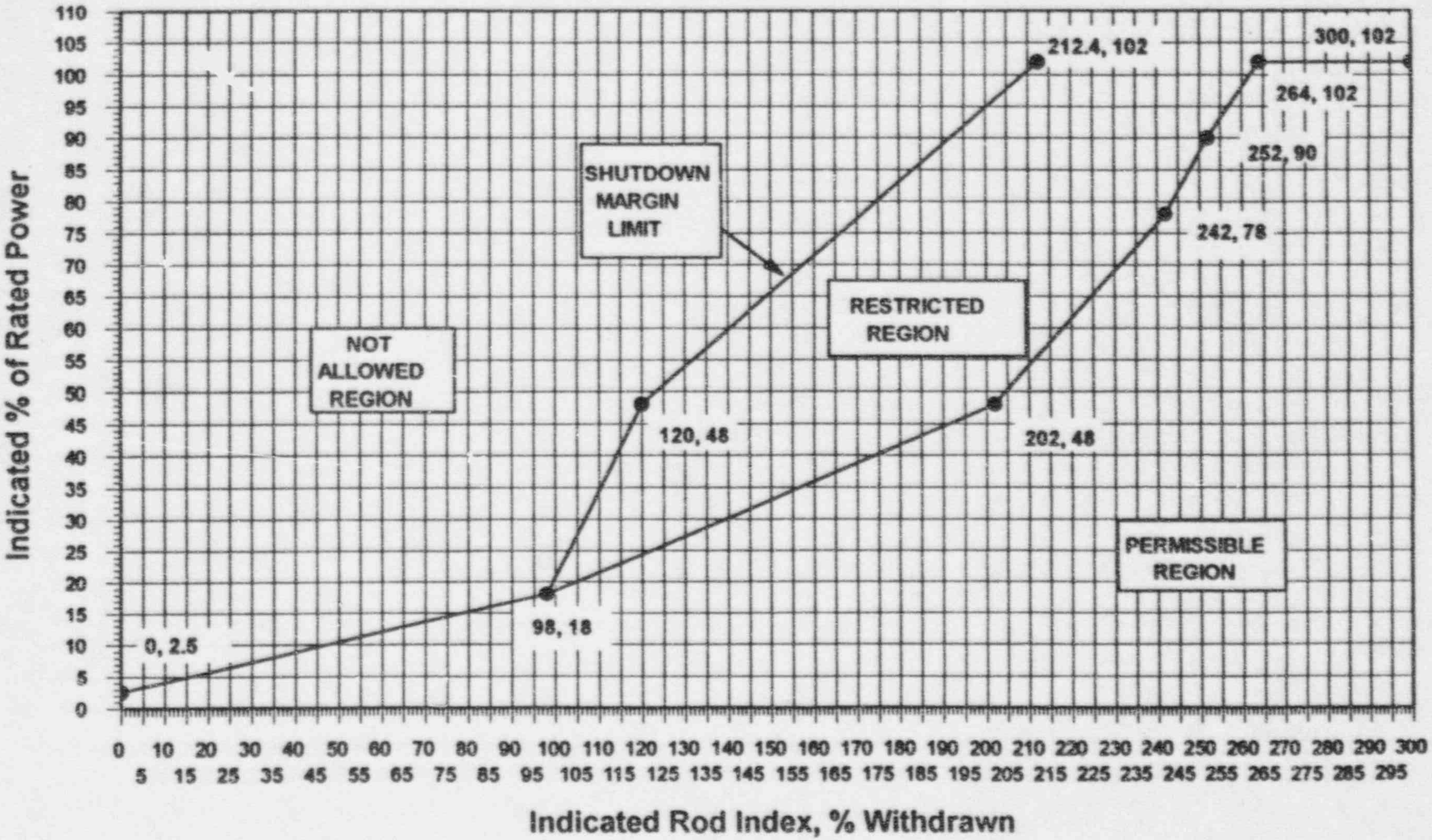
Figure 1 (Page 1 of 2)
Error Adjusted Rod Insertion Limits
0 To 75 +/-10 EFPD
4 Pump Operation



Source Doc. B&W 86-1235288-00

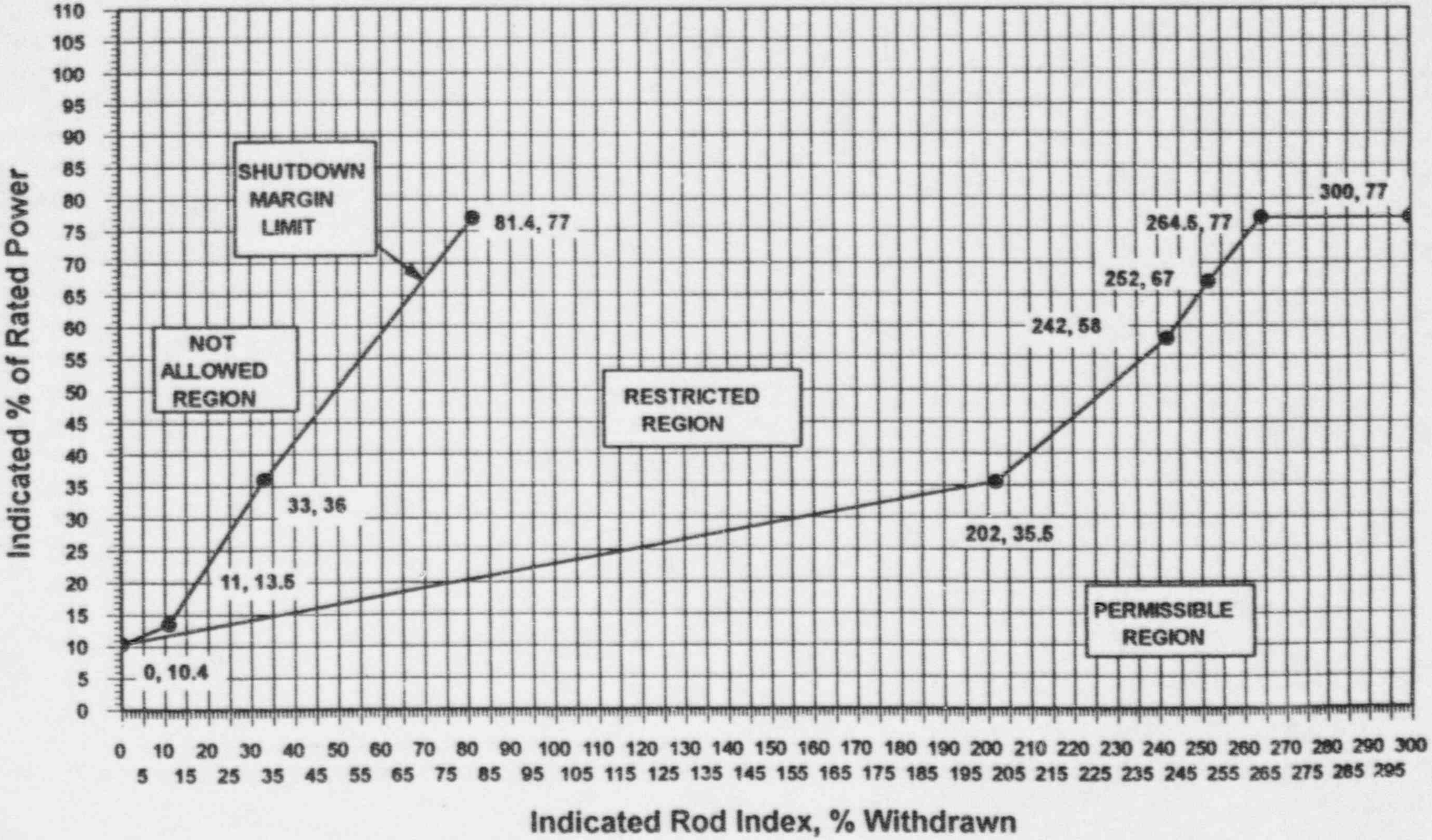
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2.

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



Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2.

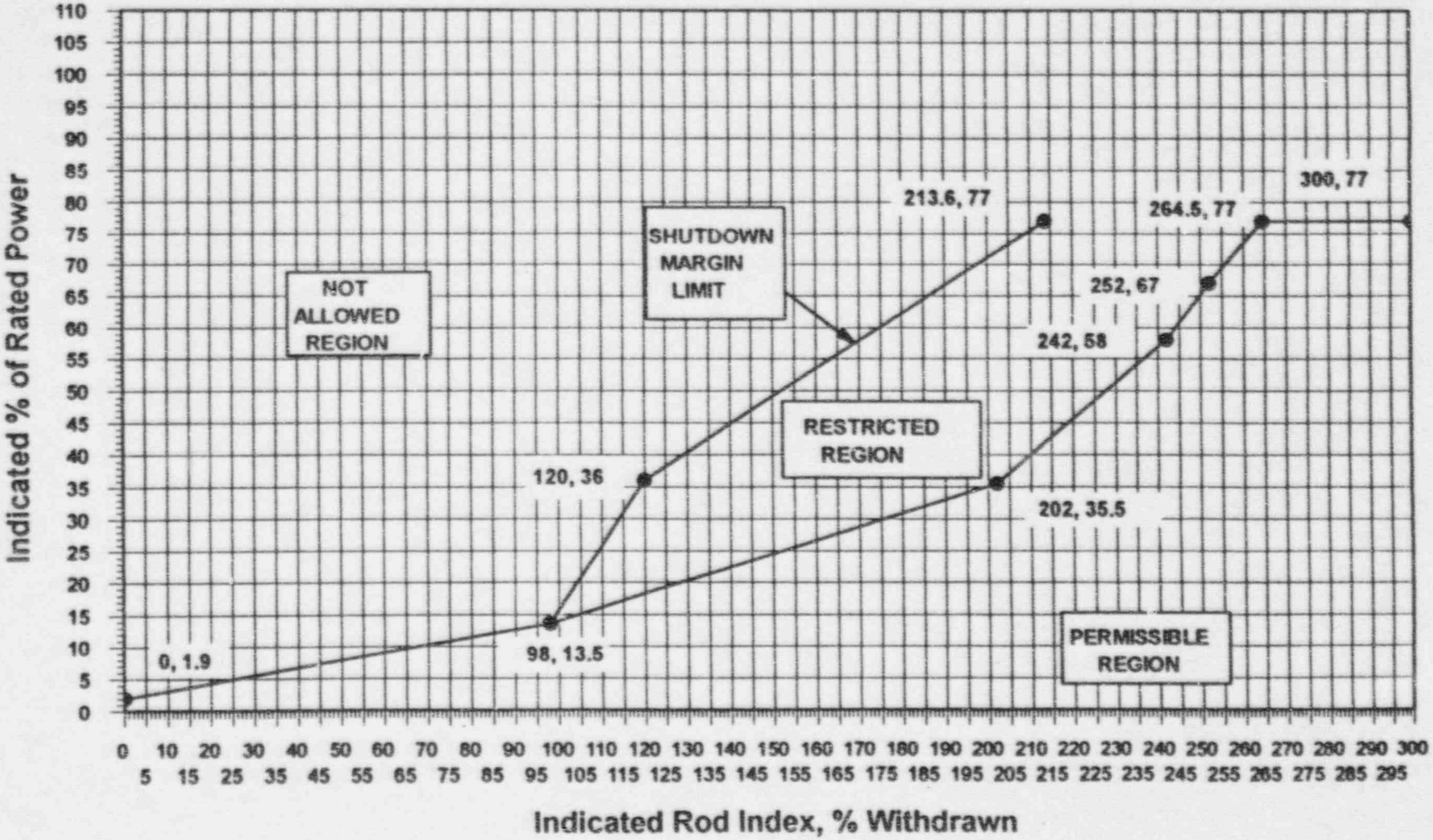
Figure 2 (Page 1 of 2)
Error Adjusted Rod Insertion Limits
0 To 75 +/-10 EFPD
3 Pump Operation



Source Doc. B&W 86-1235288-00

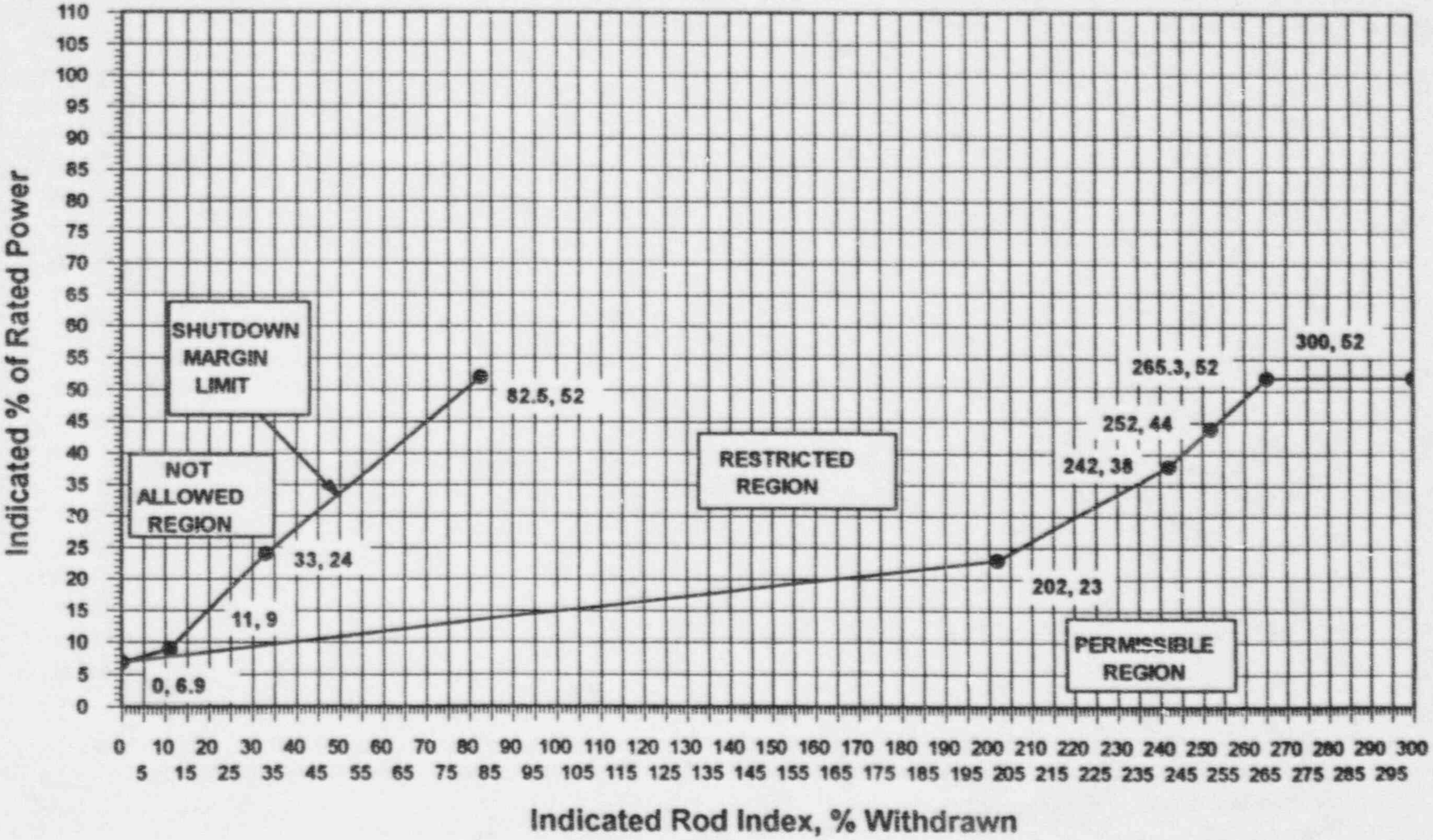
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2.

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



Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2.

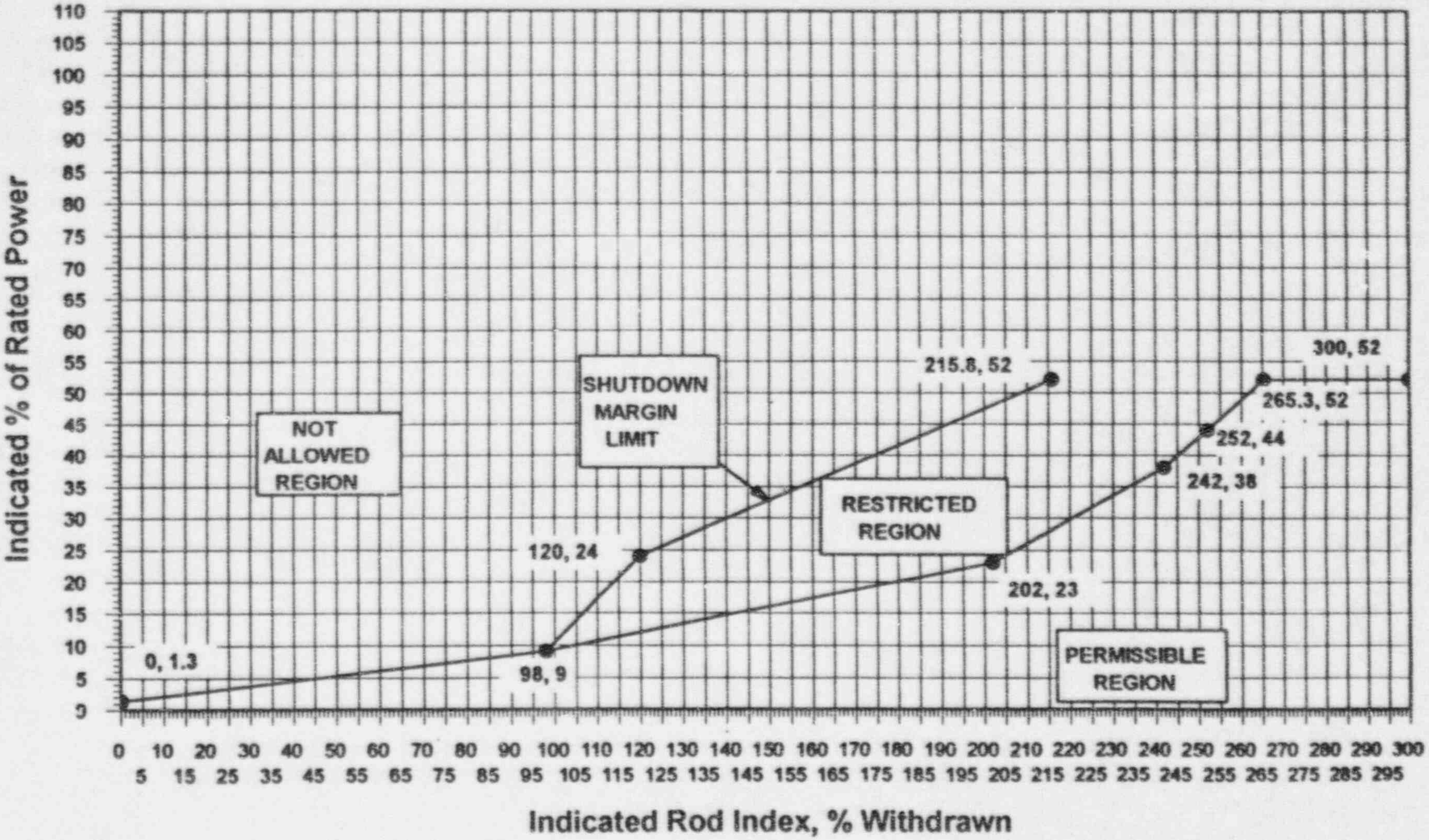
Figure 3 (Page 1 of 2)
Error Adjusted Rod Insertion Limits
0 To 75 +/-10 EFPD
2 Pump Operation



Source Doc. B&W 86-1235288-00

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

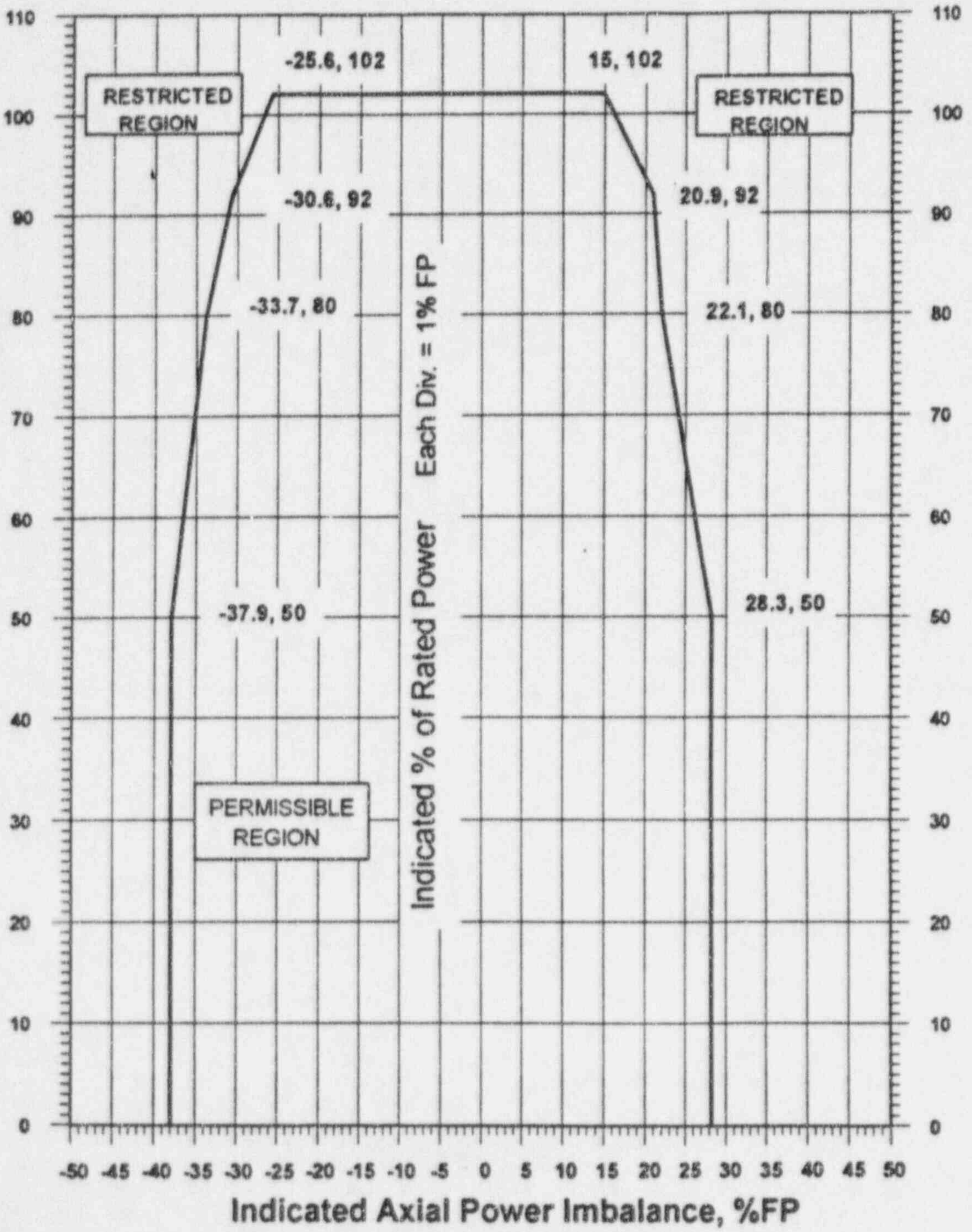
Figure 3 (Page 2 of 2)
Error Adjusted Rod Insertion Limits
75 +/-10 EFPD to EOC
2 Pump Operation



Source Doc. B&W 86-1235288-00

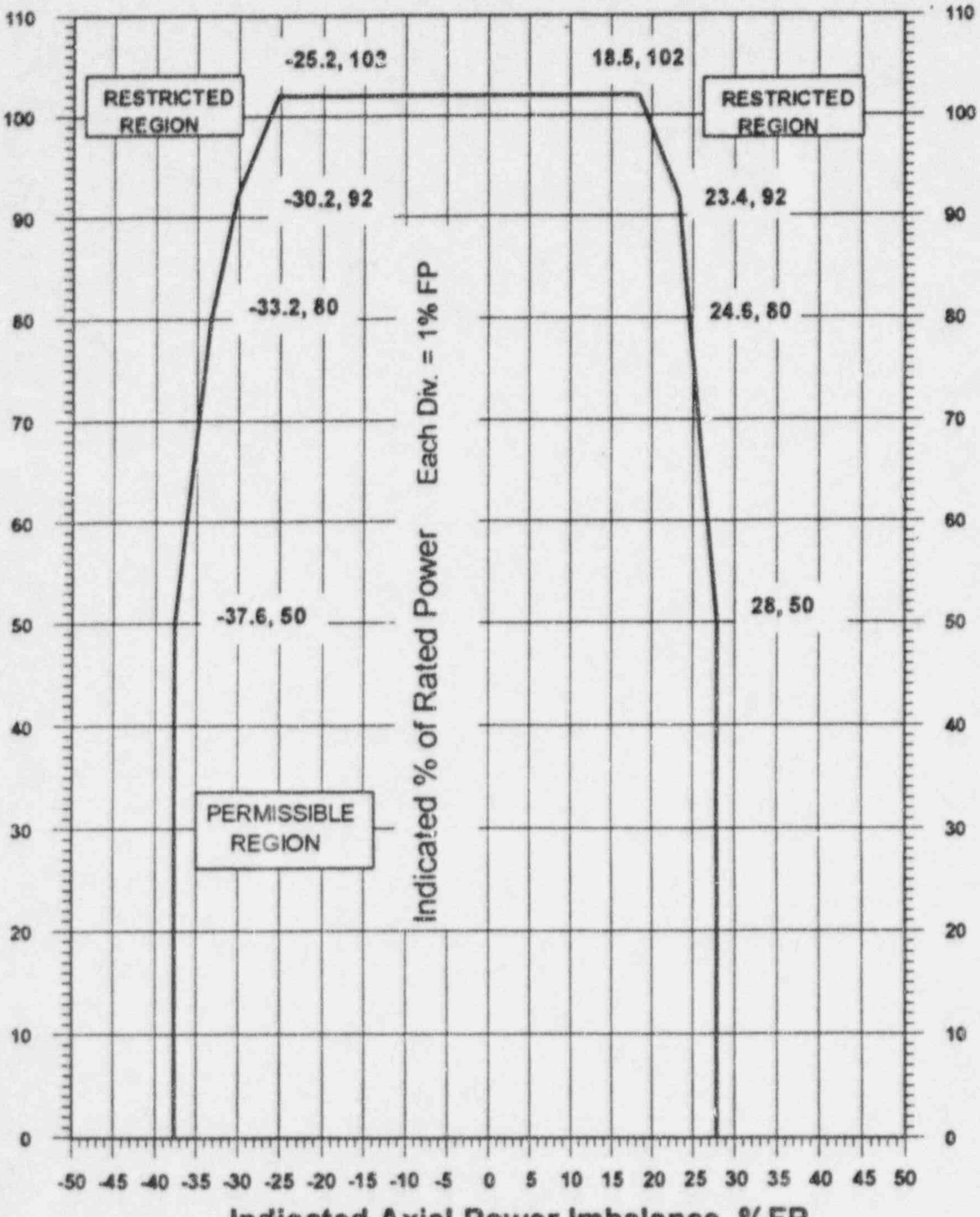
Referred to by Tech Spec 3.5.2.5.b and 3.5.2.4.e.2.

Figure 4 (Page 1 of 3)
Full Incore System
Error Adjusted Imbalance Limits
0 To 75 +/-10 EFPD



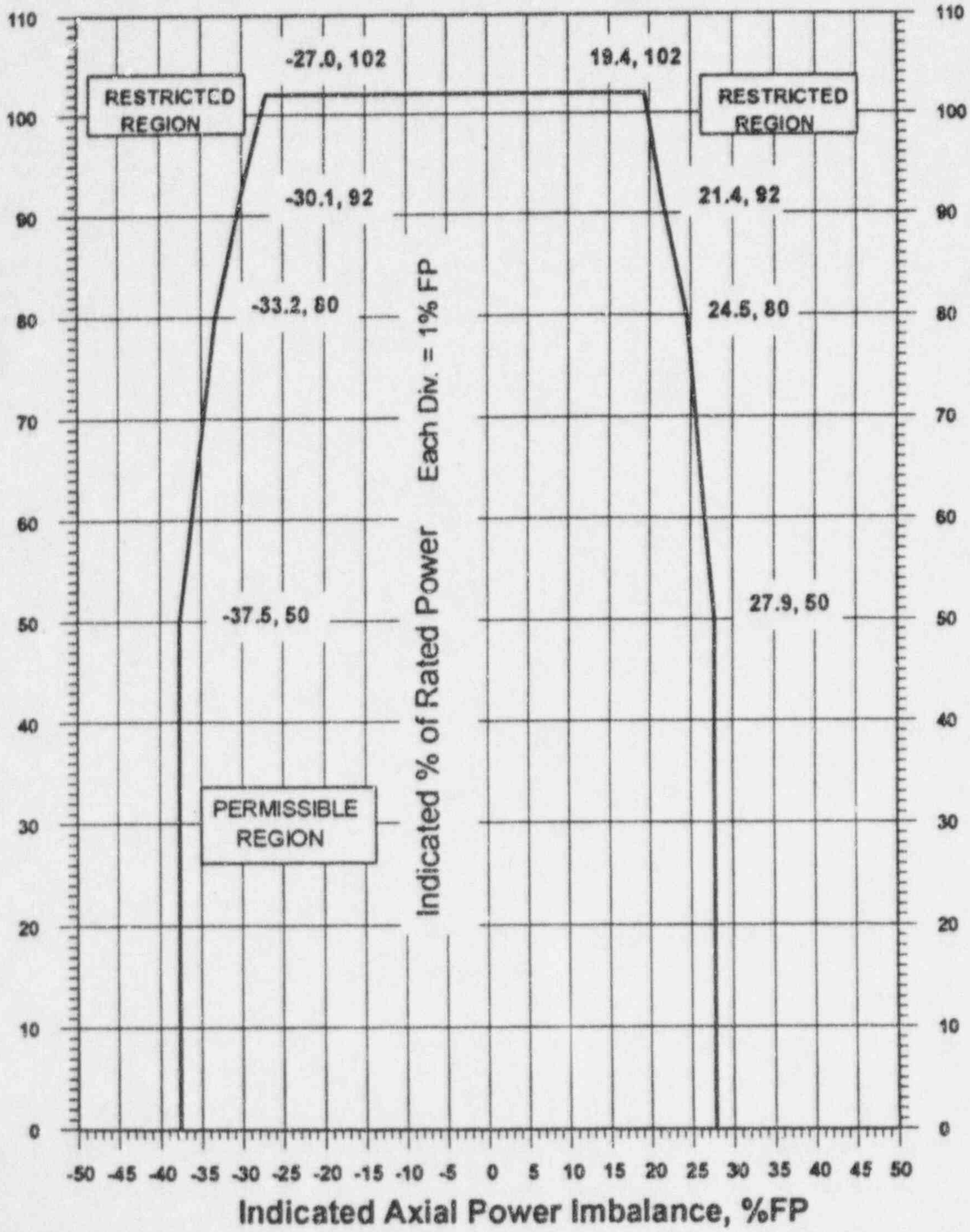
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

Figure 4 (Page 2 of 3)
Full Incore System
Error Adjusted Imbalance Limits
75 +/-10 to 500 +/-10 EFPD



Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

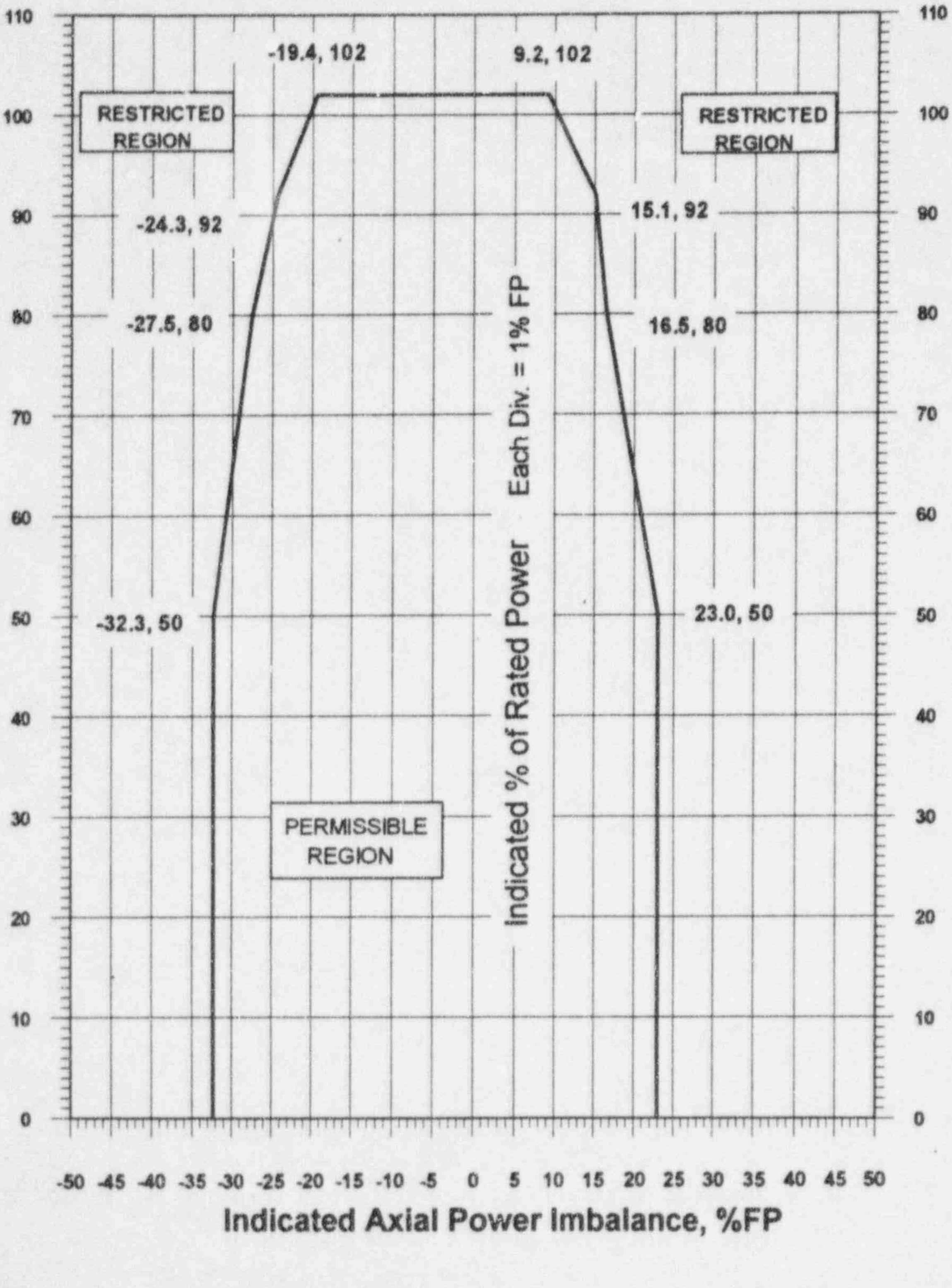
Figure 4 (Page 3 of 3)
Full Incore System
Error Adjusted Imbalance Limits
500 +/-10 EFPD to EOC



Source Doc. B&W 86-1235288-00

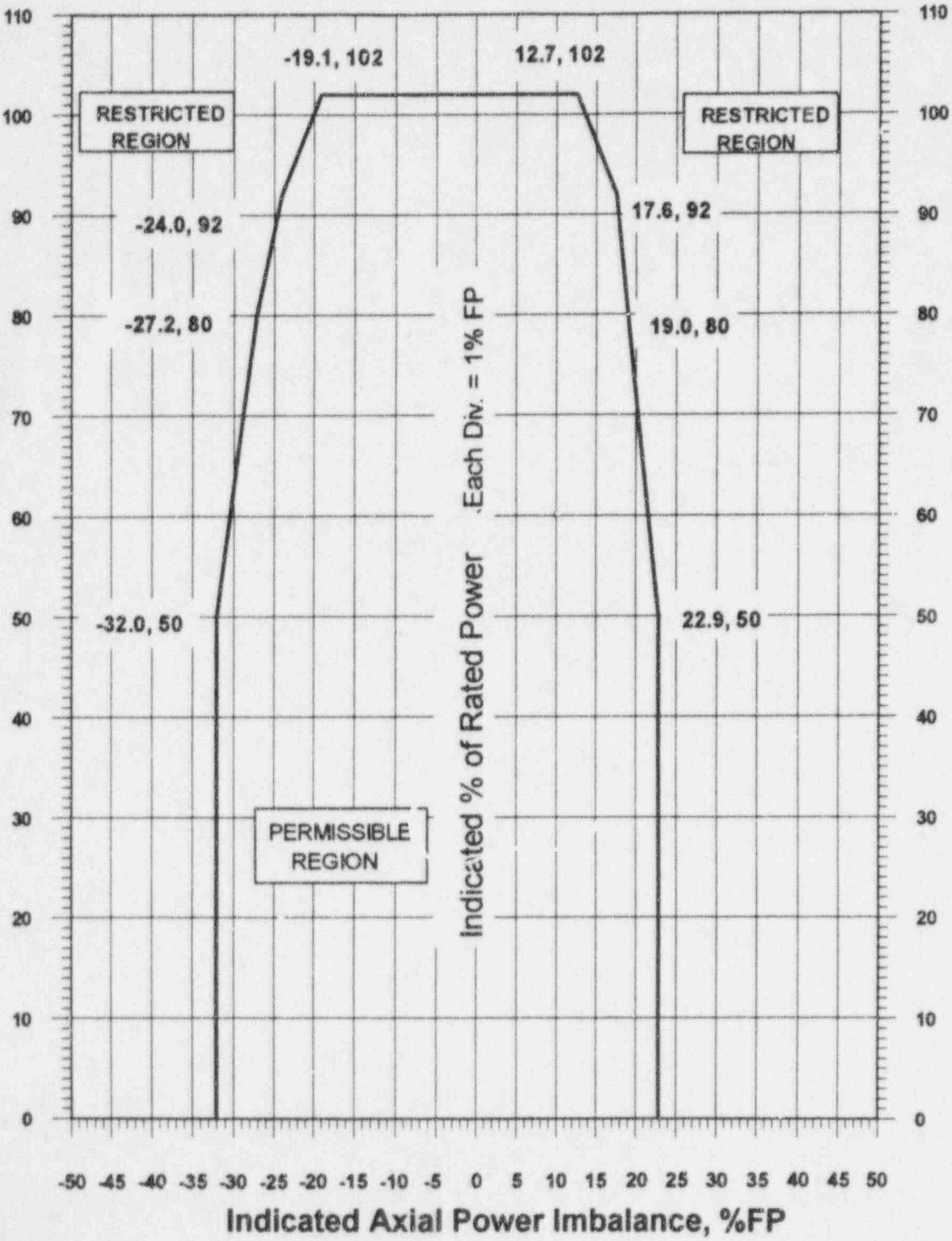
Referred to by Tech Spec 3.5.2.7.a and 3.5.2.4.e.3

Figure 5 (Page 1 of 3)
Out-of-Core Detector System
Error Adjusted Imbalance Limits
0 To 75 +/-10 EFPD



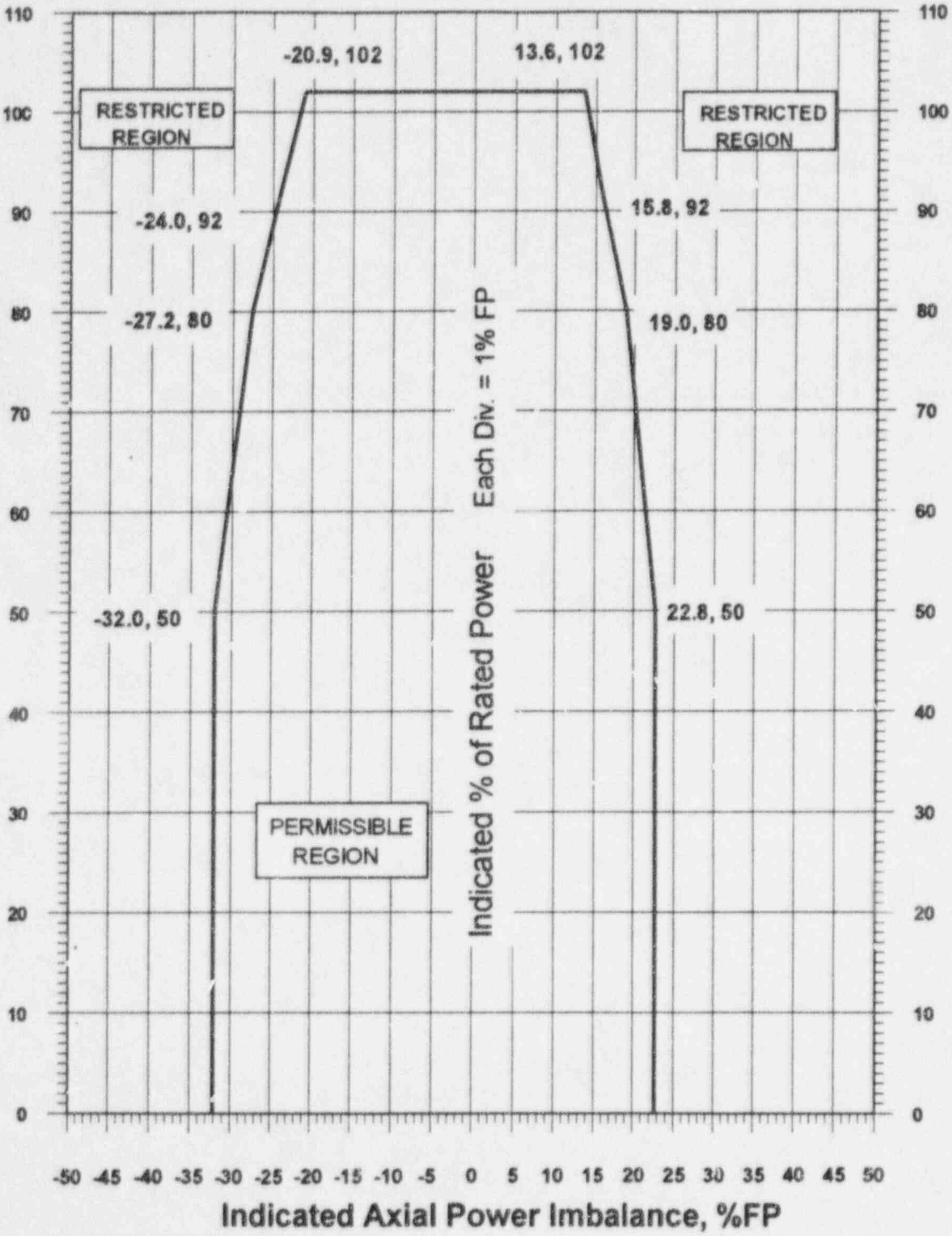
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

Figure 5 (Page 2 of 3)
Out-of-Core Detector System
Error Adjusted Imbalance Limits
75 +/-10 To 500 +/-10 EFPD



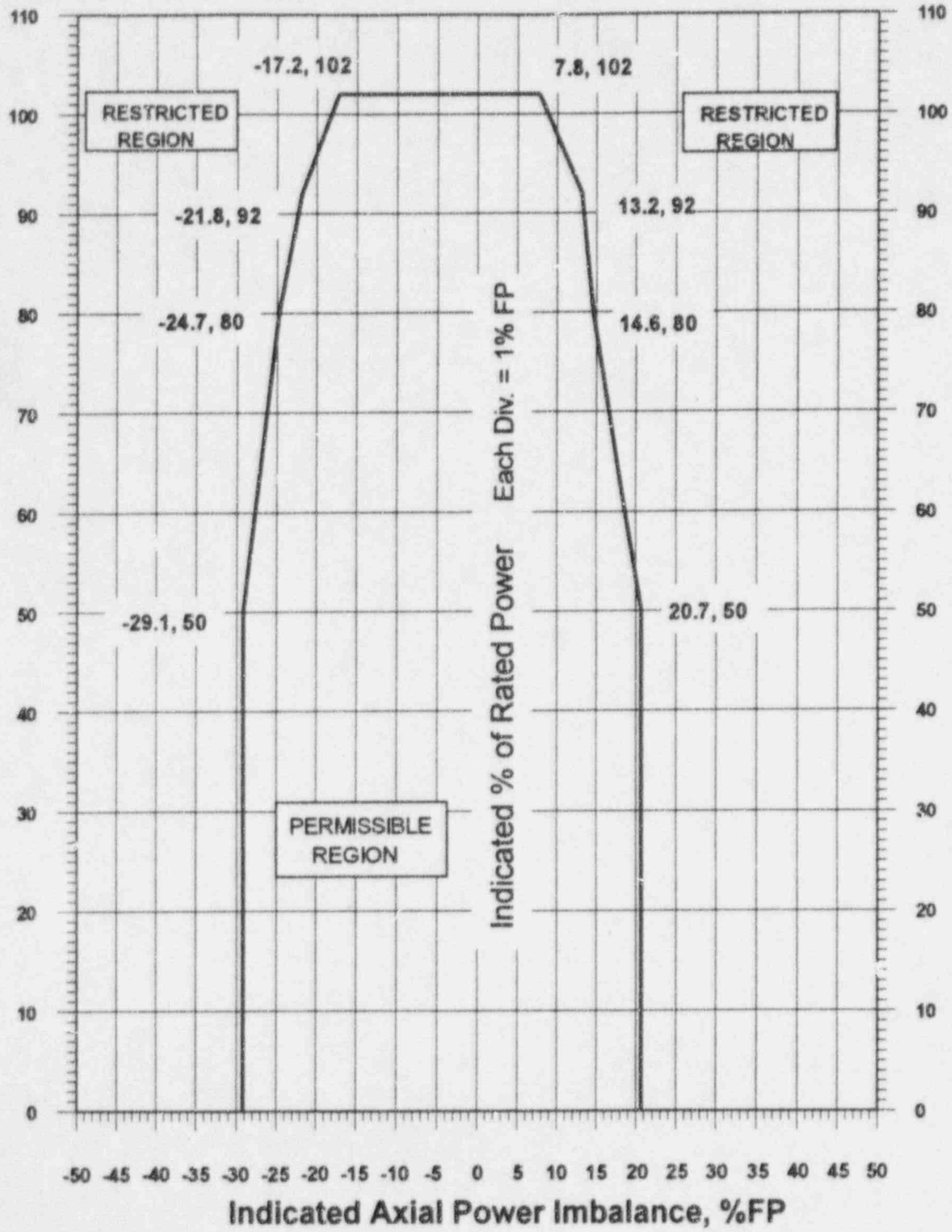
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

Figure 5 (Page 3 of 3)
Out-of-Core Detector System
Error Adjusted Imbalance Limits
After 500 +/-10 EFPD



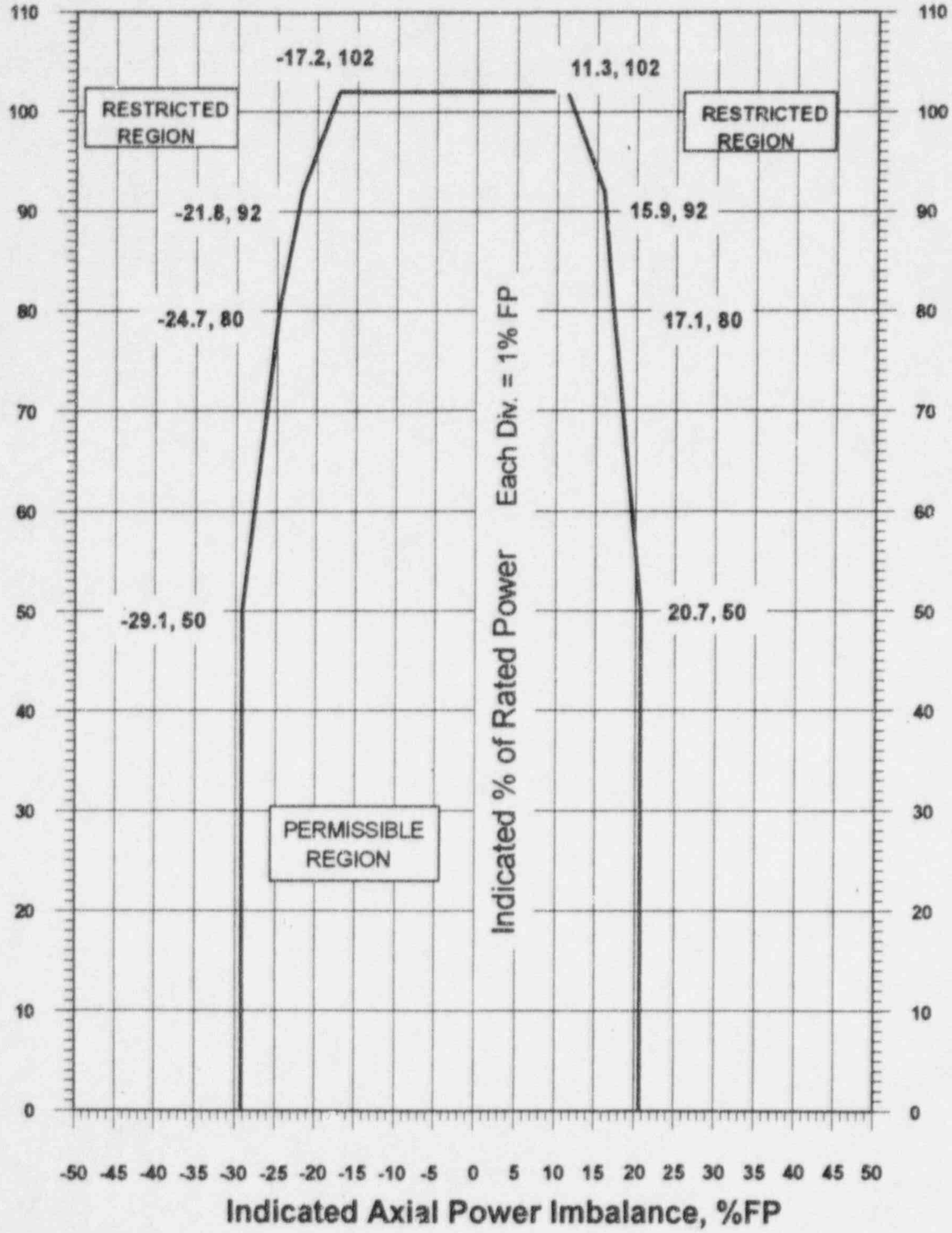
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

Figure 6 (Page 1 of 3)
Minimum Incore System
Error Adjusted Imbalance Limits
0 To 75 +/-10 EFPD



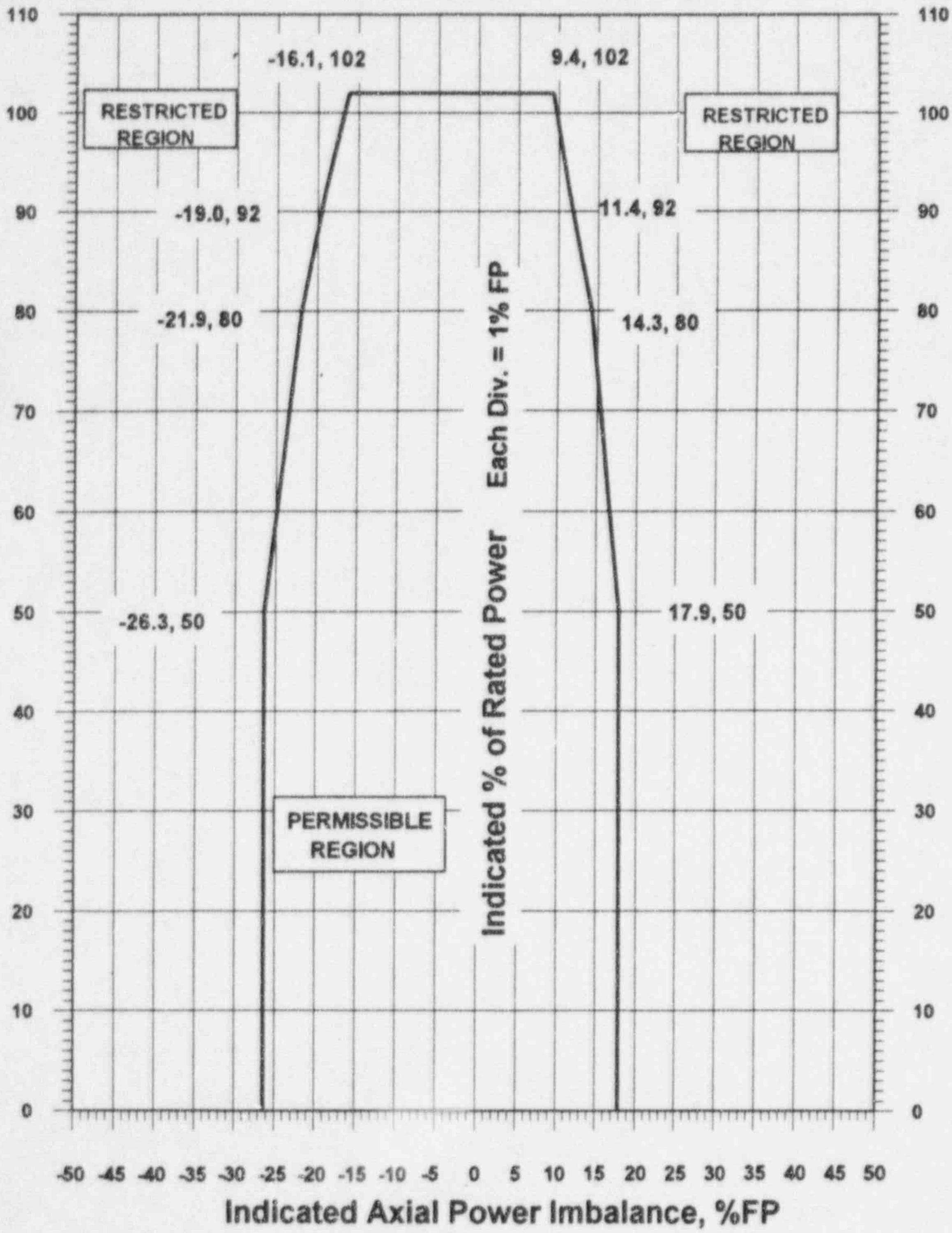
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

Figure 6 (Page 2 of 3)
Minimum Incore System
Error Adjusted Imbalance Limits
75 +/- 10 To 500 +/-10 EFPD



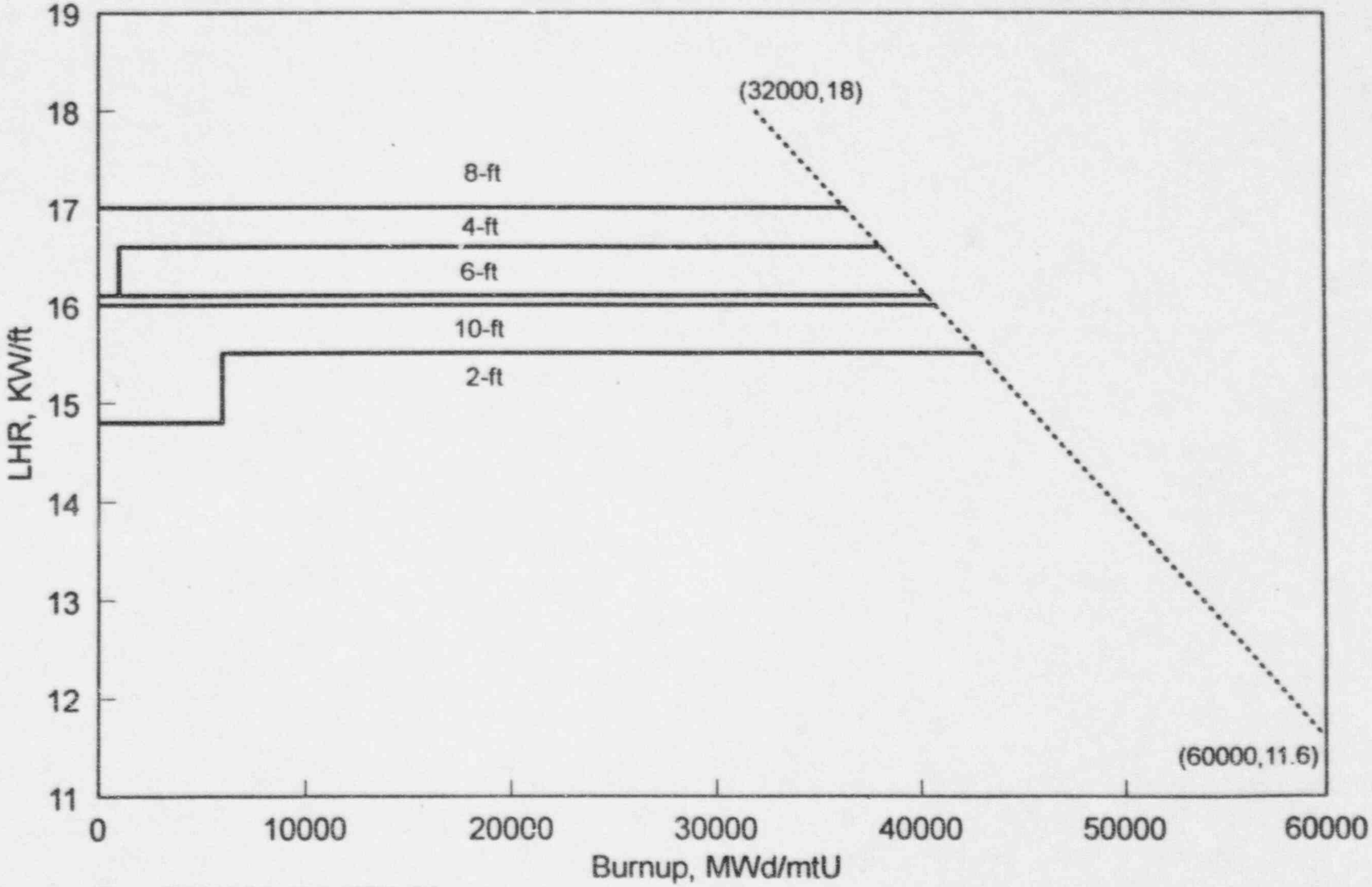
Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

Figure 6 (Page 3 of 3)
Minimum Incore System
Error Adjusted Imbalance Limits
After 500 +/-10 EFPD



Source Doc. B&W 86-1235288-00
Referred to by Tech Spec 3.5.2.7 and 3.5.2.4.e.3

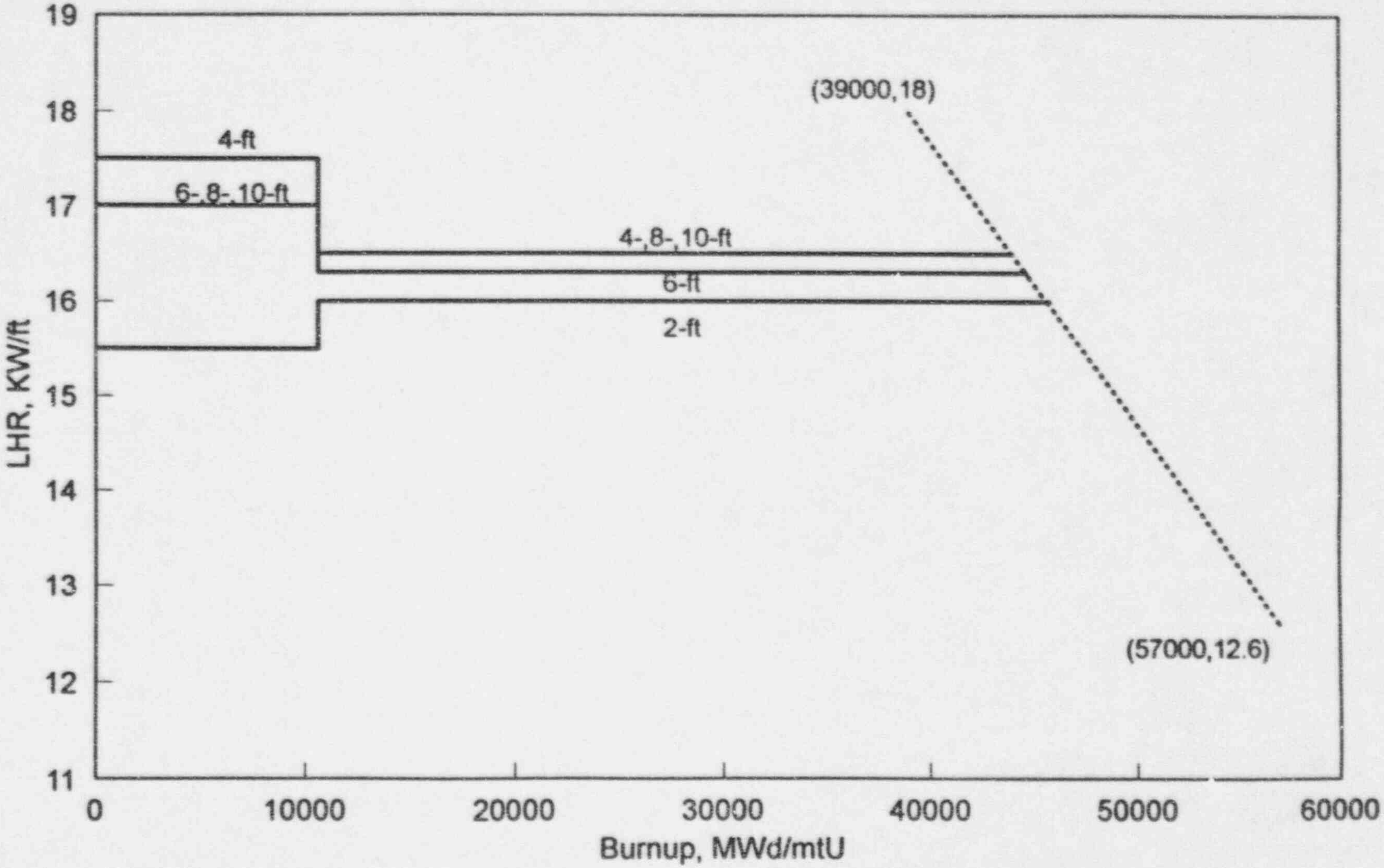
Figure 7 (Page 1 of 2)
LOCA Limited Maximum Allowable Linear Heat Rate
Mark-B8 Fuel



Source Doc. B&W 51-1234870-02
Referred to by Tech Spec. 3.5.2.8

Note: For each 1000 MWd/mtu in excess of 40,000 MWd/mtu, the linear heat rate shall be reduced linearly by 0.075 KW/ft.

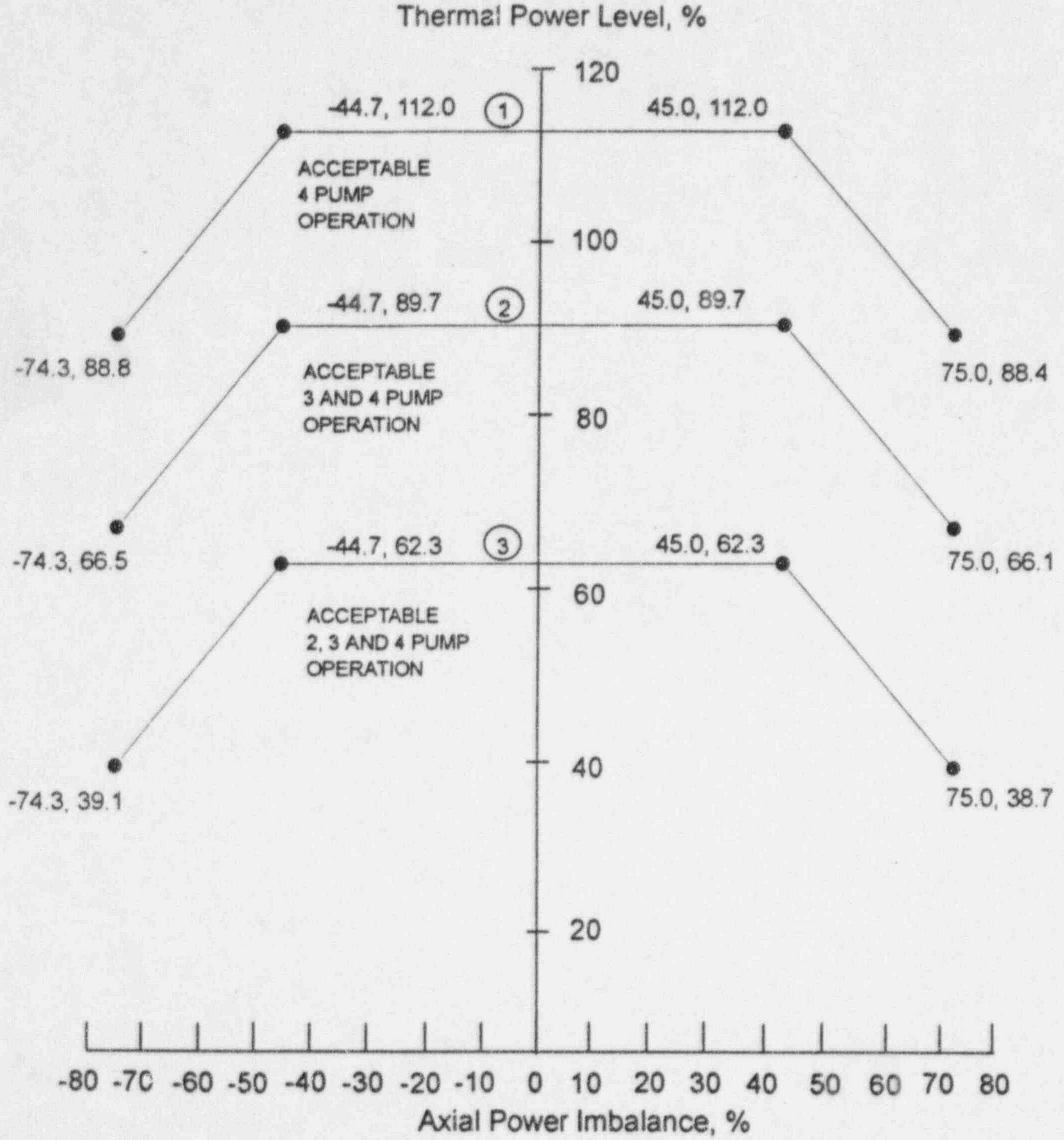
Figure 7 (Page 2 of 2)
LOCA Limited Maximum Allowable Linear Heat Rate
Mark-B9 Fuel



Source Doc. B&W 51-1234870-02
Referred to by Tech Spec 3.5.2.8

Note: For each 1000 MWd/mtu in excess of 40,000 MWd/mtu, the linear heat rate shall be reduced linearly by 0.075 KW/ft.

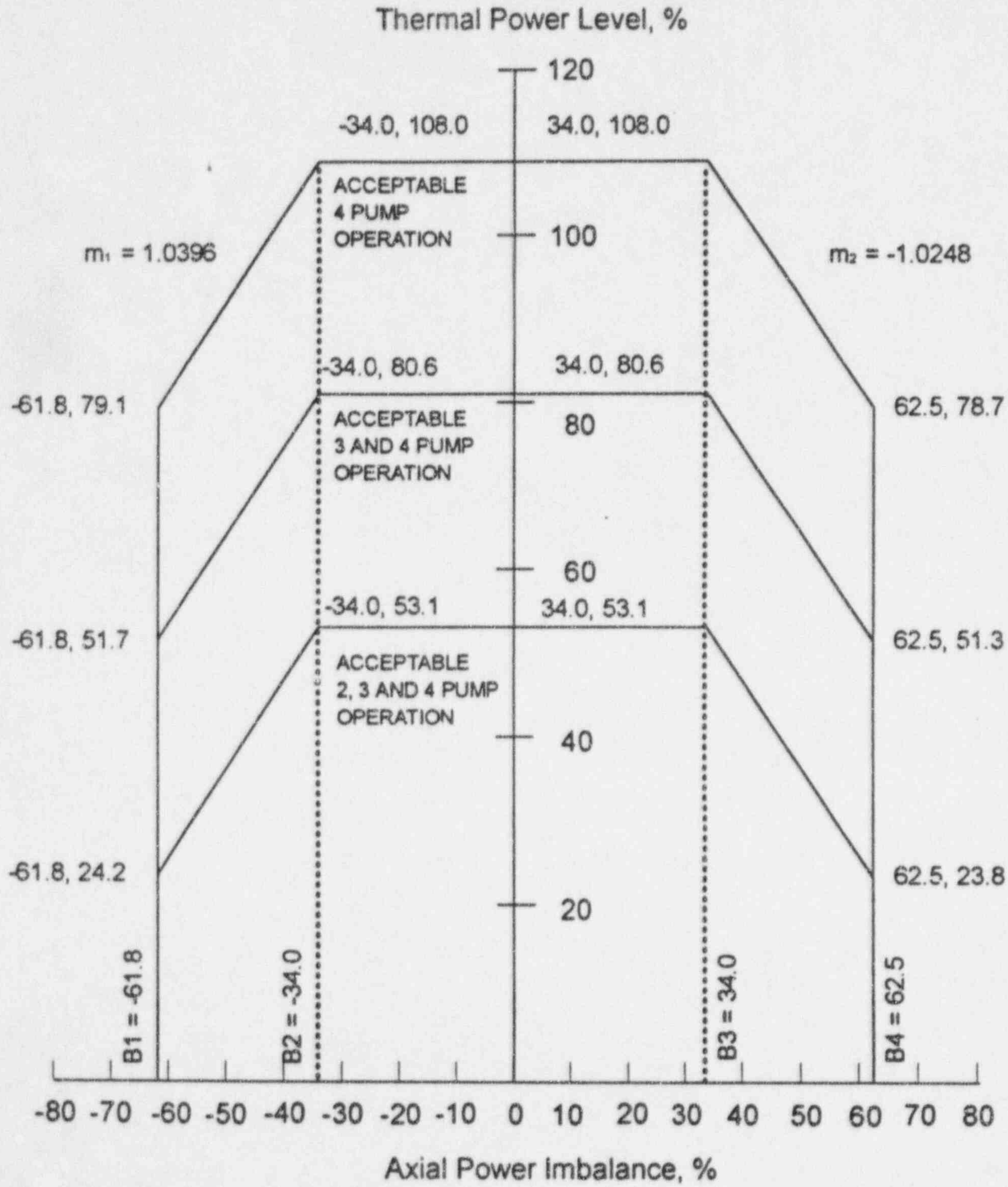
Figure 8
AXIAL POWER IMBALANCE PROTECTIVE LIMITS



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. BWNT 86-1234922-01

Figure 9
PROTECTION SYSTEM MAXIMUM ALLOWABLE SETPOINTS FOR AXIAL POWER IMBALANCE



Source Doc. BWNT 86-1234922-01

Enclosure 1

Operating Limits Not Required by Technical Specifications

1. <u>Core Minimum DNBR Operating Limit</u>

(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. <u>Maximum Allowable Local Linear Heat Rate Limits</u>

(Reference: T.S. 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. Power-to-Flow Trip Setpoints

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 T.S. 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: T.S. 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

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

$F^N_q = 2.82$