UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 22, 1985

Docket No. 50-29

LICENSEE: Yankee Atomic Electric Company

FACILITY: Yankee Nuclear Power Station

SUBJECT: MEETING SUMMARY - MEETING WITH YAECO ON ECCS CODE REVISION

A meeting was held between Yankee Atomic Electric Company (YAECo) and the NRC staff to discuss proposed revisions to the ECCS codes and code assumptions for the Yankee plant. The meeting was held in Bethesda, Maryland on August 8, 1985 at the request of YAECo. A list of attendees is provided in Enclosure 1. The meeting agenda and objectives are provided as Enclosure 2.

After a brief introduction by the NRC and YAECo project managers, the licensee provided discussions regarding the reasons for the current reevaluation of the Yankee ECCS codes, the Yankee plant characteristics, the core flux shapes and associated uncertainties, the history of the Yankee ECCS code development, and proposals for modifying the ECCS codes and input assumptions to assure continued compliance with 10 CFR 50.46. A more detailed discussion of each of these presentations is provided in the following paragraphs. The handouts used for these presentations are provided in Enclosures 3 and 4.

In its introduction, the licensee explained that it was informed in the Spring of 1985 that the axial power shapes it had been using for ECCS analyses may no longer be acceptable to the NRC staff. Specifically, the cosine shaped axial power shape had been questioned. The licensee explained that it had taken action to limit flux in the upper core region by operating with a rodded core which ensured a bottom-peaked power distribution. This provided assurance that Yankee remained in compliance with 10 CFR 50.46 while the ECCS analysis methods were being reviewed. The desirability of operating the Yankee core in a rodded condition was discussed. since this is not the normal operating mode for Yankee. The licensee and the staff also discussed the likelihood that the staff's concern for compliance with 10 CFR 50.46 was not a safety issue due to the conservatisms that the licensee felt existed in the Yankee ECCS codes. A more detailed discussion of the code conservatisms was provided by Yankee later in the meeting.

The licensee provided a discussion on the Yankee core power distributions (Enclosure 3). Following a description of the plant characteristics, the licensee described its calculated flux distributions for Cycle 18 (Enclosure 3, pages 5-8). The graphs show nominal flux distributions for various times in core life, and show the effects of xenon on the flux

distributions. As shown on page 8 of Enclosure 3, the calculated xenon transient induces a top-peaked power distribution late in core life. In response to a staff question, the licensee explained that load-following calculations for xenon transient evaluation were performed at full-power steady state conditions, with Technical Specification (TS) limits that require the plant to be held at a reduced power following a power transient to limit the effects of the xenon transients if the rods are outside the rod insertion limit shown on pages 3 and 19 of this enclosure. The licensee then described the self-damping characteristics of the xenon transient following a rod-induced power transient (Enclosure 3, pages 9 and 10).

The licensee then provided the NRC staff with a comparison of actual measured flux levels against calculated levels to show that the current codes estimate flux levels within approximately 1%, except at the outermost regions of the core. The comparison was provided for the current and previous cores (cores 17 and 16). Graphs of calculated versus actual axial flux distributions are provided on pages 17 and 18 of Enclosure 3, which show a close comparison between calculated and actual axial flux.

The licensee provided a discussion of the administrative controls currently in place at Yankee to provide assurance that the requirements of 10 CFR 50.46 are met with the current code for Cycle 17. The licensee has added administrative controls to limit control rod movement which limits power levels in the upper core region to limit any top peaked power distribution. In addition, current TS have a restriction on how soon after a power reduction the core can be returned to full power if the rod heights are outside the rod insertion limit, and there is a restriction on rod reactivity transient rates. Both of these TS restrictions serve to limit the effect of xenon transients on the axial flux distribution. The licensee has stated that the additional restriction on rod withdrawal limits will remain in effect until reaching 80% power during the power coastdown. Compensation for xenon transients will be accomplished using boron, to keep the rods within the administrative restriction.

To show the effects of operating with a rodded core, graphs were provided showing the axial flux distribution with and without the rod restriction, at two times in core life (page 20, 21, Enclosure 3). Page 22 (Enclosure 3) shows the effect on xenon transients with and without the rod restriction. The graphs point out that the flux distribution is bottom-peaked with the rodded core, which has the plant within the original analysis assumptions for cycle 17 operations. The graph on page 23 (Enclosure 3) further shows the effect of reactivity rates on the axial power distribution, which points to the reason for maintaining the TS limits on reactivity rates.

The licensee then provided information regarding the conservatisms in the LOCA limits of Linear Heat Generation Rate (LHGR) vs. core burnup. The licensee presented information regarding conservatisms that exist in the Xenon Redistribution Factor (Fxe) and the Rod Insertion Factor (Fi). The licensee also discussed three other factors (the Measurement Uncertainty (Fu), the Power Uncertainty (Fp), and the Engineering Factor (Fe)) in the TS LHGR limit. The licensee proposes to combine these three factors statistically, as opposed to the current method of combining them multiplicatively, as discussed on page 27 of Enclosure 3. The NRC staff

stated its belief that based on the information presented in the meeting, statistically combining the three factors (Fu, Fp, and Fe) should be acceptable. The NRC staff stated that the licensee should provide its justification for this proposal to allow for NRC staff review.

The next three slides (pages 28-30, Enclosure 3) show information regarding the integration of boron dilution with control rod motion, to support the Yankee proposal to use nominal flux shapes in its calculations, as opposed to the current approach of using the xenon-induced flux shapes. The slide on page 30 (Enclosure 3) shows the difference in axial flux shapes for the nominal and xenon shapes, and shows a bottom-peaked power distribution for the nominal case, and a top-peaked distribution for the xenon case.

Following the presentation, the NRC staff pointed out that the normal analysis assumptions consider TS allowable transients (i.e., if TS allow rod motion between 80-90 inches, the analysis should use these limits). In addition, the NRC staff stated that administrative controls may not be appropriate, but that the TS should be modified appropriately. The licensee provided the argument that the nominal approach is more like the way the plant operates, and therefore should be used for the calculations. The NRC restated its position of using the limiting analysis for the licensing basis. On the issue of using a statistical combination of the uncertainties, the NRC staff stated that similar proposals from other licensees have been accepted, while others have not, on the merits of the individual cases. The NRC staff would need to look at the details of the Yankee proposal. The NRC staff stated that the information to be provided by the licensee needed to include an appropriate data base, and to show independence of the factors involved. Based on the information presented at the meeting, the NRC staff felt that the Yankee approach to statistical combination of uncertainties was appropriate, but that the staff would have to see the specifics before making its final determination.

The NRC staff then questioned the licensee regarding plans for removing Fi and Fxe from the LHGR calculations. The licensee felt that a bottom shaped flux distribution bounded the cosine curve, and Fi would not be needed in the calculation. In the consideration for Fxe, the current TS value for Fxe would be modified as a part of the cycle 18 reload submittal, and the licensee is considering other restrictions (e.g., rod motion limits) that may eliminate the need for Fxe. As part of the reload submittal, the licensee intends to make a case for eliminating the Fxe bottom mutiplier (page 26 of Enclosure 3).

The licensee presented information related to the LOCA analysis methods that are being investigated (Enclosure 4). The licensee explained the history behind the previous analyses performed up through cycle 17. The analysis for cycle 18 had been performed using the cosine shaped flux distribution, and the licensee explained that the calculations would need to be re-performed based on the current NRC concerns. To complete the reanalysis, the models that are currently being used will have to be modified in order to remove the operating rod withdrawal restrictions to allow operation without a rodded core. In 1975, the licensee had identified the Yankee models, explaining the differences between the Yankee model and the generic effort based on the Exxon model being used for the H.B. Robinson plant. Since Yankee was using the cosine-shaped flux

distribution, it used Fi and Fxe mutipliers to add additional conservatism. Since the initial code development, a number of changes have been made to the Yankee model as more knowledge or limitations in codes have been identified. The latest questions regarding the Yankee ECCS codes deal with conditions during the reflood phase of the accident analyses (after the blowdown and refill phases have ended). Based on the current concerns, a composite flux distribution was used to perform the LOCA analyses. The composite distribution included the most limiting of the cosine and the physics-determined flux distributions.

The technical issue of concern in the reflood phase was to not have the flux peak in the upper core region because of the time it took to reflood that region. In the previous analyses using the cosine shaped flux distribution, the flux peak was in the core midplane, and as long as the peak remained below this core midplane, the analysis using the cosine shape would be bounding. The current analysis which identified a top-peaked power distribution led to rod withdrawal restrictions to provide flux suppression in the upper core region to obtain a bottom peaked flux distribution, and therefore make the cosine shaped flux distribution again bound the actual flux distribution. Page 6 of Enclosure 4 shows the licensee's proposed operating restrictions for the power coastdown phase of the operating cycle. This page shows that rod withdrawal above the current restriction of 83 inches will be necessary. To allow for this, the licensee proposed a rod withdrawal rate limit of less than or equal to 2 inches per day to ensure the analysis' peak centerline temperature (PCT) remains less than 2200 degrees post-LOCA.

The licensee then provided a discussion of the cycle 18 analyses that have been performed to date. Page 8 (Enclosure 4) shows the items the licensee is requesting regarding the model and analysis parameter changes for its model. One of the issues shown deals with an injection delta-P penalty, which is a conservatism included in the model to account for pressure loss due to injection parameters of angle and flow rate. The licensee is currently using a 90 degree angle of injection, which results in a delta-P penalty of 0.8 psid. With a modified model, the licensee proposes a delta-P penalty of 0.15 psid. The staff's initial impression is that there should not be any problem in granting a modification of the delta-P penalty, but the staff needs to evaluate the licensee's calculations and assumptions before making a final decision.

The NRC staff questioned the appropriateness of using nominal power shapes in the licensee's calculations. The licensee explained that it intends to perform a series of power shape calculations, which are an extension of burnup sensitivity studies, using calculated flux shapes, not the TS limits. The licensee acknowledged that this approach needs to be justified. The TS would then be based on a calculation to allow operating margin providing for errors in calculations compared to measured flux levels. This extra margin has in past efforts resulted in calculations based on TS kW/ft limits to show possible problems in meeting Appendix K. The licensee had then proposed a single TS limit which would be limiting, or bounding, and be shown to be limiting based on sensitivity studies. The staff pointed out that the licensee's efforts to meet Appendix K would be helped by using a variable limit on the kW/ft limit based on core height.

The licensee explained the differences between its analyses and the Westinghouse methods (which result in a variable kW/ft limits). The licensee explained that to show one kW/ft limit, as opposed to a variable one,

sensitivity studies are needed to show the limit is bounding. The current Yankee kW/ft TS limits are based on cosine-shaped flux distribution calculations. The licensee is working on developing kW/ft TS limits based on a top-peaked flux distribution, and add a known amount of conservatism. for its variable kW/ft limits. Westinghouse uses height-dependent flux (F delta H) limits for departure from nucleate boiling (DNB) and hot channel calculations. These same limits are used in the Westinghouse LOCA calculations. The Yankee model does not use F delta H in its LOCA model. The licensee does not feel there are any radial flux (Fxy) dependencies in the LOCA calculations, and therefore uses kW/ft instead. It was also noted that Westinghouse shows compliance with Appendix K in pre-cycle calculations, while Yankee verifies compliance throughout the cycle using actual measurements to compare to its calculations.

The licensee then explained that if the delta-P penalty modification is approved, there would be no need to benchmark the modified Yankee model, due to the nature of the changes. The licensee also pointed out that this change in its model would be a permanent change. The licensee proposed to provide the changes to the model as a separate enclosure to the reload package. The staff felt it would be more appropriate to provide the LOCA model changes in a separate letter, while at the same time use the modified model in the cycle 18 submittal. The staff felt that Yankee had provided sufficient information in the meeting such that the NRC staff feels the change to the model will be acceptable, pending confirmation of the information provided at the meeting. The licensee stated that if a problem with the cycle 18 analyses or the TS were to occur, the fallback position would be to rely on current TS with rod restrictions.

The licensee stated that as it develops its final proposal, it may ask for additional conference calls or meetings to discuss its approach with the staff. This approach is acceptable to the staff. The licensee was asked to provide a letter of commitment, to include the bases for removing the current rod restrictions, including any additional restrictions that may be necessary during the power coastdown, as discussed earlier in the meeting.

The licensee asked one additional question regarding whether the proposed modifications to the Yankee LOCA model would have to be prenoticed as a license amendment. The staff's position is that the proposed modifications, other than the TS that result from the calculations, are of such a nature that the license is not being modified, and therefore would not require prenoticing.

The resident inspector noted that with the changes in operating restrictions proposed by the licensee, the Licensee Event Report (LER) would need to be modified. The licensee agreed to submit a modified LER.

The meeting was adjourned. The staff took special note of the forthright approach presented by the licensee in this meeting, and also noted the sound and timely technical efforts that have been expended by the licensee in its investigations of the LOCA model.

James W. Clifford

James W. Clifford, Project Manager
Operating Reactors Branch No. 5

Enclosures:
1. List of Attendees
2. Meeting Agenda
3. Core Power Distribution Handouts
4. LOCA Analysis Methods Handouts

cc w/enclosures:
See next page

cc:
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ENCLOSURE 1

MEETING WITH YAECo RE: ECCS Codes

NAME	AFFILIATION
Jim Clifford	NRC/NRR/DL
JOHN A ZWOLINSKI	NRC/NRR/DL
GEORGE PAPANIC JR	YAEC
John D. HASELTINE	YAEC
DONALD HUNTER	YAEC
AUSAF HUSAIN	YAEC- LOCA Group
RICHARD J. CACCIAPOUTI	YAEC - REACTOR PHYSICS
Marvin Dunenfeld	NRC/CPB
HOWARD RICHINGS	" "
Robert Jones	NRC/RSB
Bill SZYMCZAK	YAEC - LOCA GROUP
Kevin J. Morrissey	YAEC
Bruce C. Slifer	YAEC - Nuclear Eng. Dept.
HAROLD EICHENHOLZ	NRC/RESIDENT INSPECTOR
GREGORY A. MARET	YAEC — REACTOR ENGINEERING
Norman Lauben	NRC/RSB

ENCLOSURE 2

AGENDA

YANKEE PLANT AXIAL POWER SHAPE MEETING

10:00 INTRODUCTION — B. C. Slifer

10:15 CORE POWER DISTRIBUTIONS — R. J. Cacciapouti

- -Yankee Core Characteristics
- -Typical Axial Power Shapes
- -Xe Transients: Durations and Axial Shapes
- -Cycle 17 Measured vs. Predicted Power Distributions
- -Impact of Rod Program on Cycle 17 Power Shapes
- -Core Power Monitoring
- -Application of Uncertainty Factors
- -Basis for Cycle 18 Power Shapes

11:15 LOCA ANALYSIS — A. Husain

- -Background Information
  - -Basis for Previous Analyses
  - -Axial Power Shape Discussions to Date
  - -Response to NRC Letter of May 22, 1985
- -Analysis for Cycle 17
- -Analysis for Cycle 18
  - -Prospective Methods Improvements
  - -Axial Power Shapes

12:00 DISCUSSION

- -Cycle 18 Schedules
- -Basis for Cycle 18 Analysis

BCS
8/8/85

OBJECTIVES

1. To explain actions taken to assure compliance with 10CFR50.46 for Cycle 17.

2. To explain actions planned to assure compliance with 10CFR50.46 for Cycle 18.

3. To obtain NRC feedback on
   a) basis for axial power shapes for LOCA analysis
   b) statistical combination of uncertainties
   c) injection ΔP penalty reduction

4. To discuss Cycle 18 schedules.

5. Time permitting, to discuss future LOCA methods improvements.

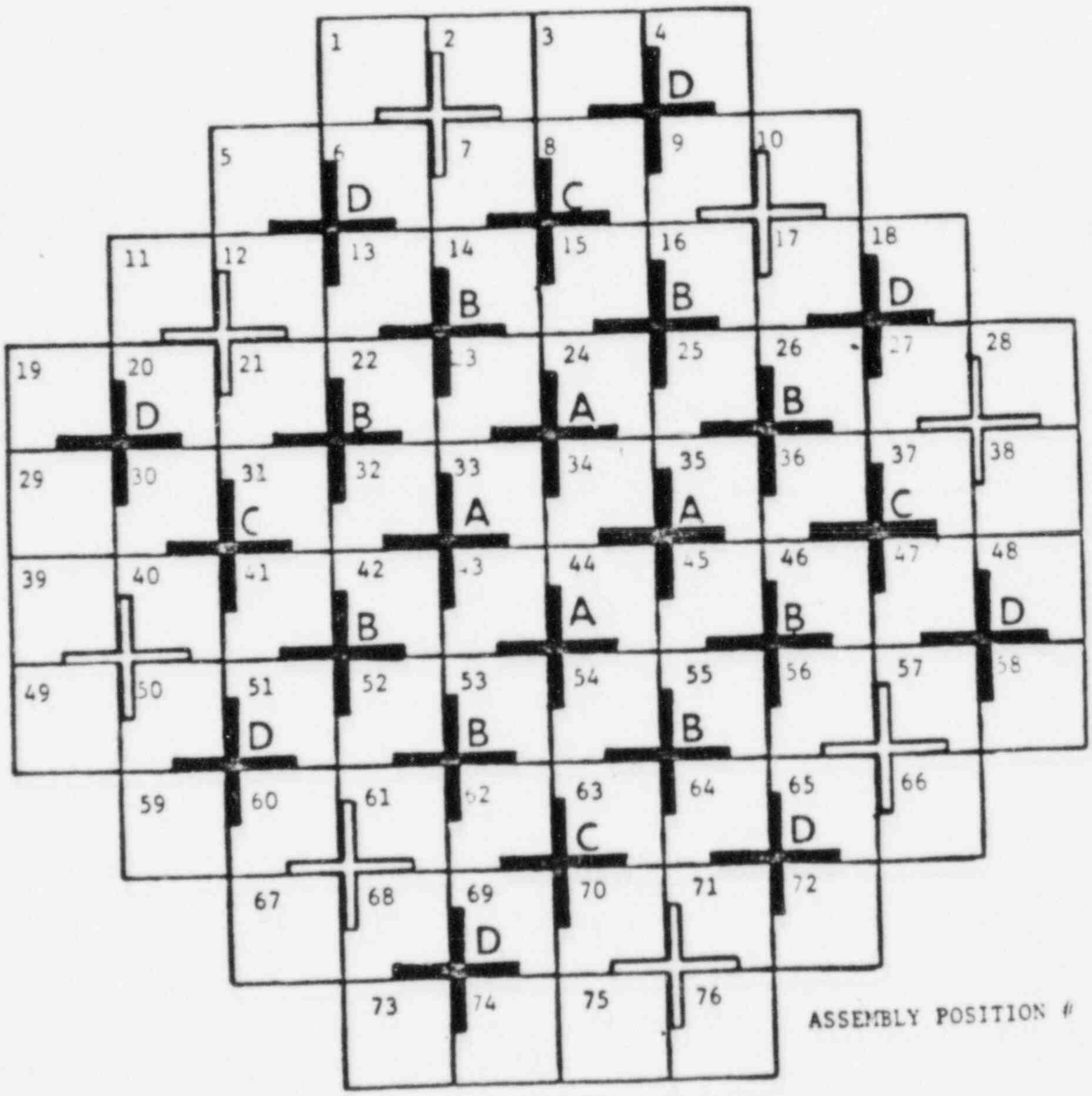
BCS
8/8/85

YANKEE ROWE CHARACTERISTICS

POWER LEVEL	600 MWT
NUMBER OF ASSEMBLIES	76
RODS PER ASSEMBLY	230/231
ACTIVE HEIGHT	7.5 ft.
CONTROL ROD	
TYPE	CRUCIFORM
NUMBER	24
GROUPS	4
MATERIAL	Ag-In-Cd

CONTROL ROD GROUP

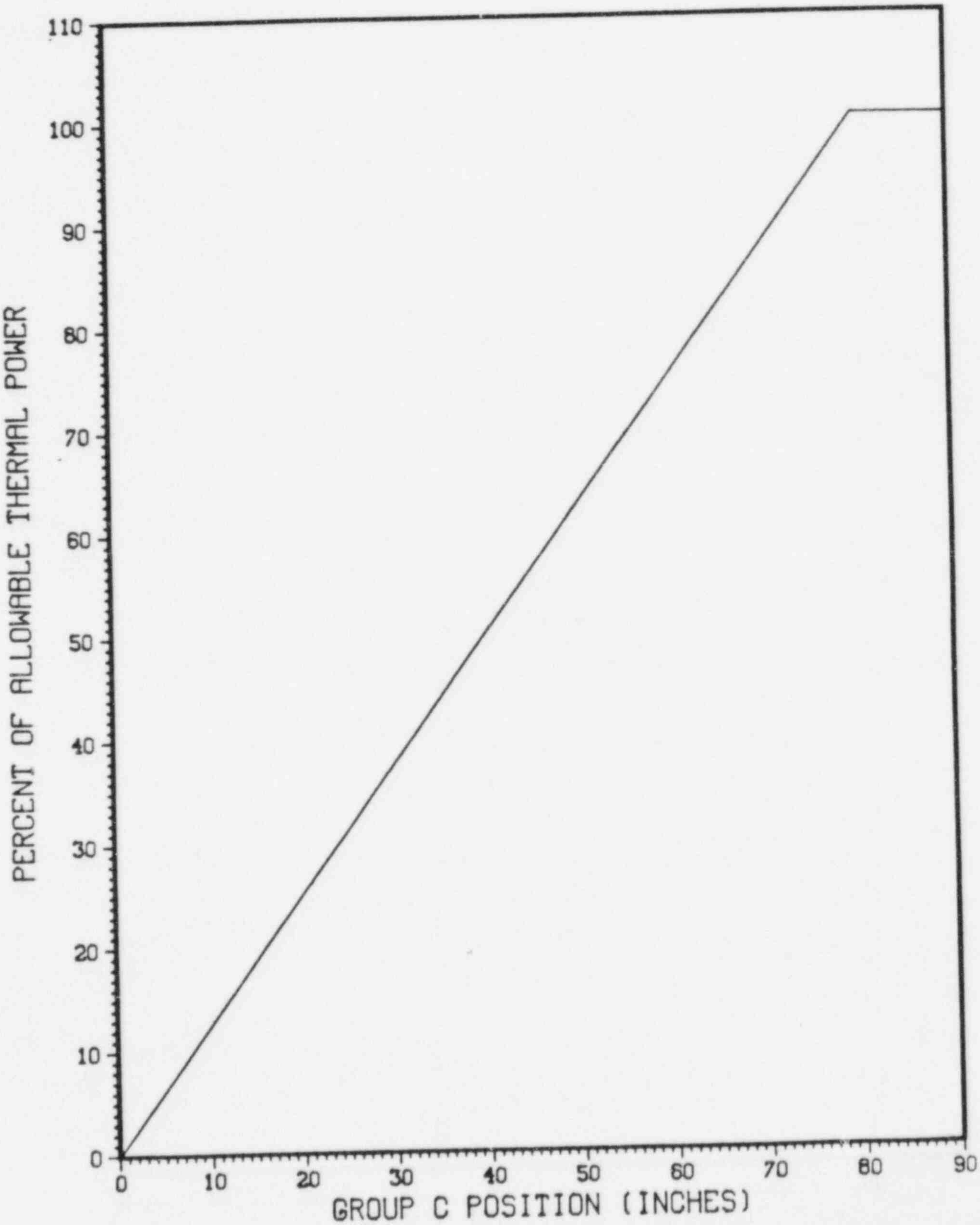
IDENTIFICATION



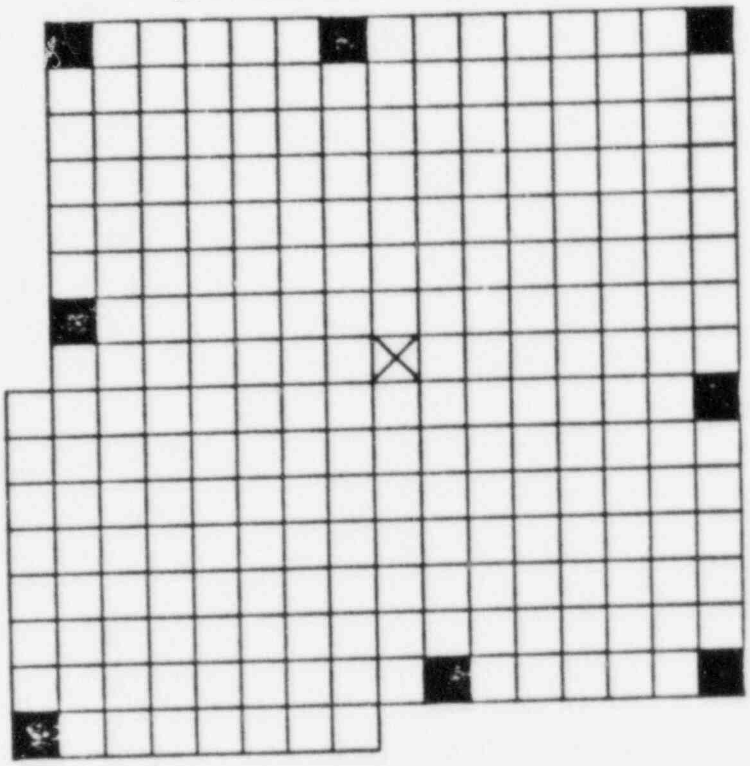
ASSEMBLY POSITION #

YANKEE CORE 17

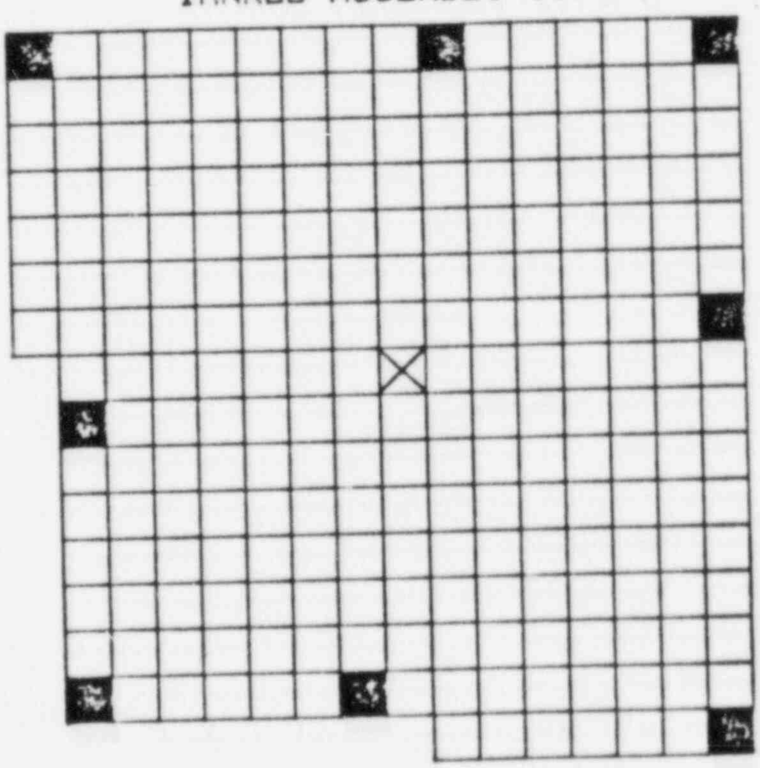
POWER DEPENDENT INSERTION LIMIT

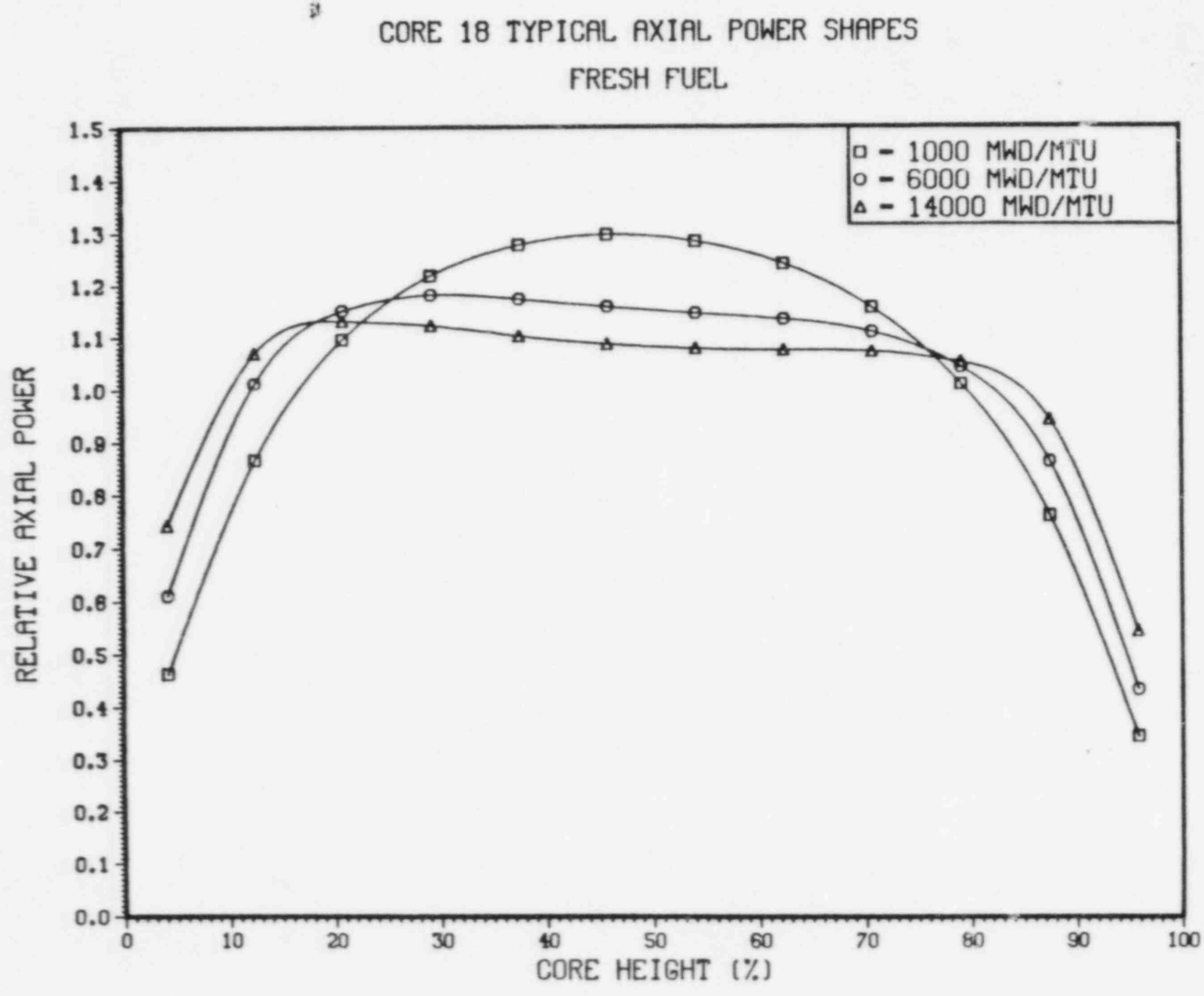


YANKEE ASSEMBLY TYPE A



YANKEE ASSEMBLY TYPE B

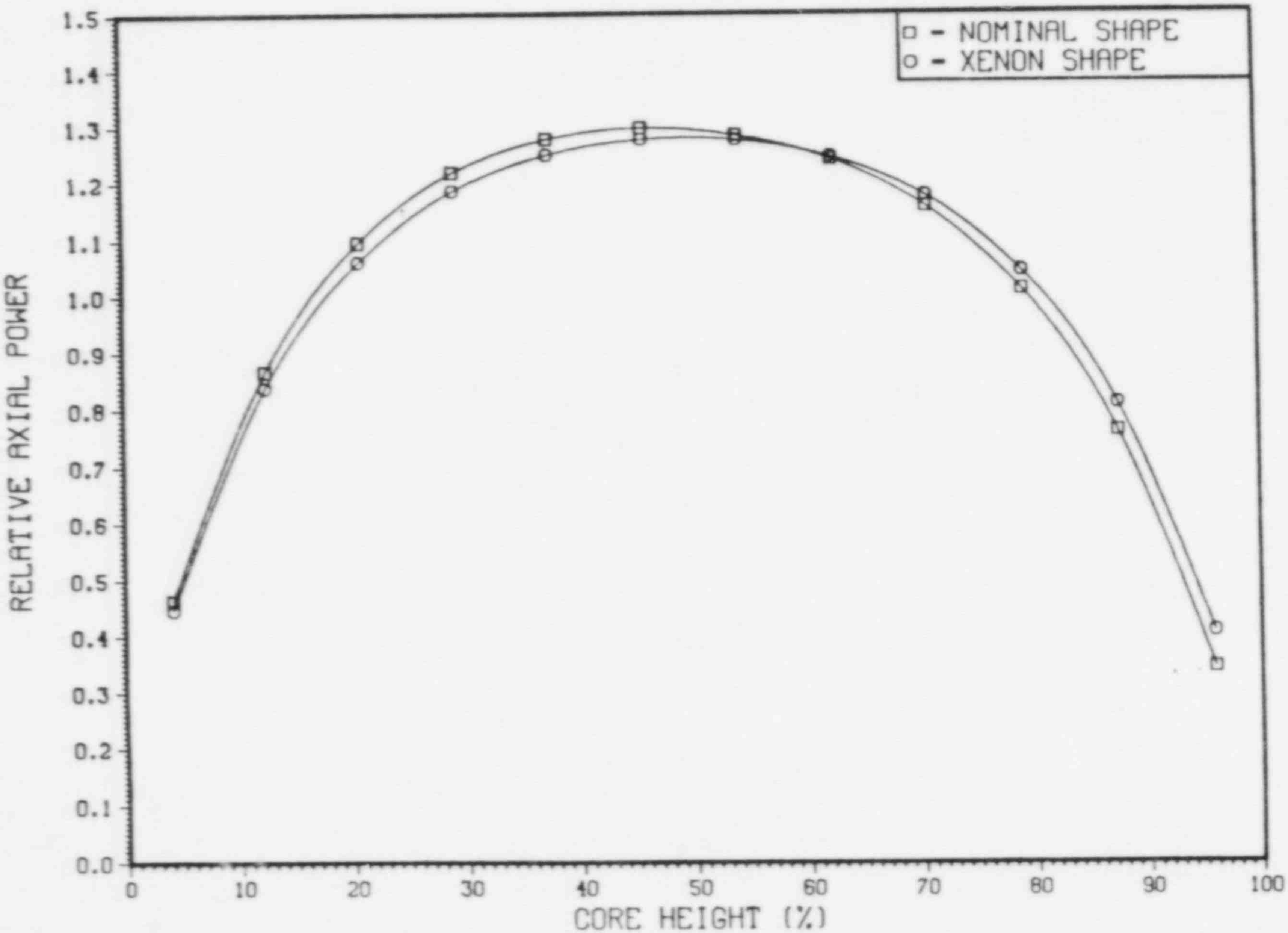



CORE 18 TYPICAL AXIAL POWER SHAPES
FRESH FUEL
□ - 1000 MWD/MTU
○ - 6000 MWD/MTU
△ - 14000 MWD/MTU
RELATIVE AXIAL POWER
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)

5

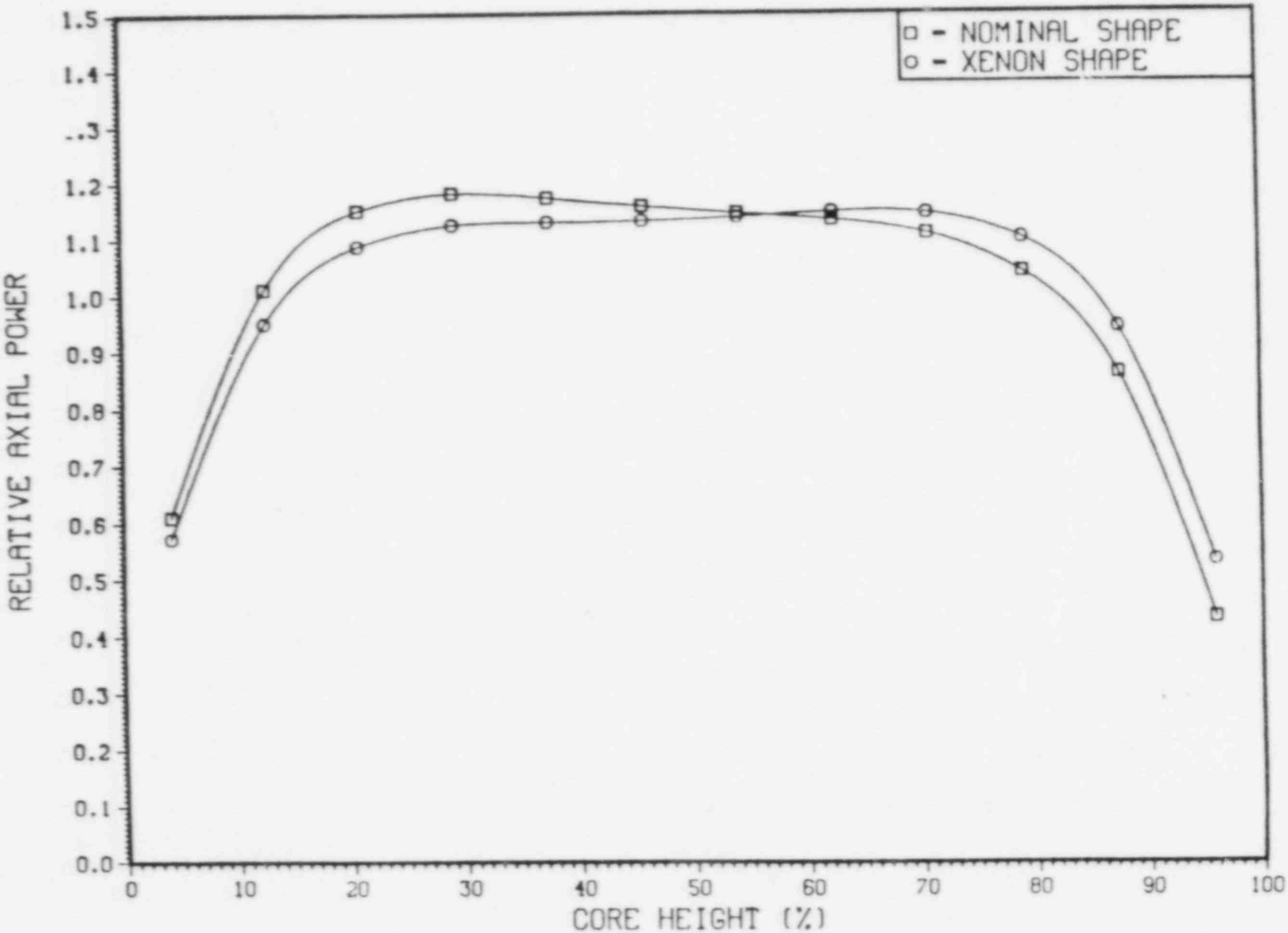
CORE 18 NOMINAL AND XENON POWER SHAPES

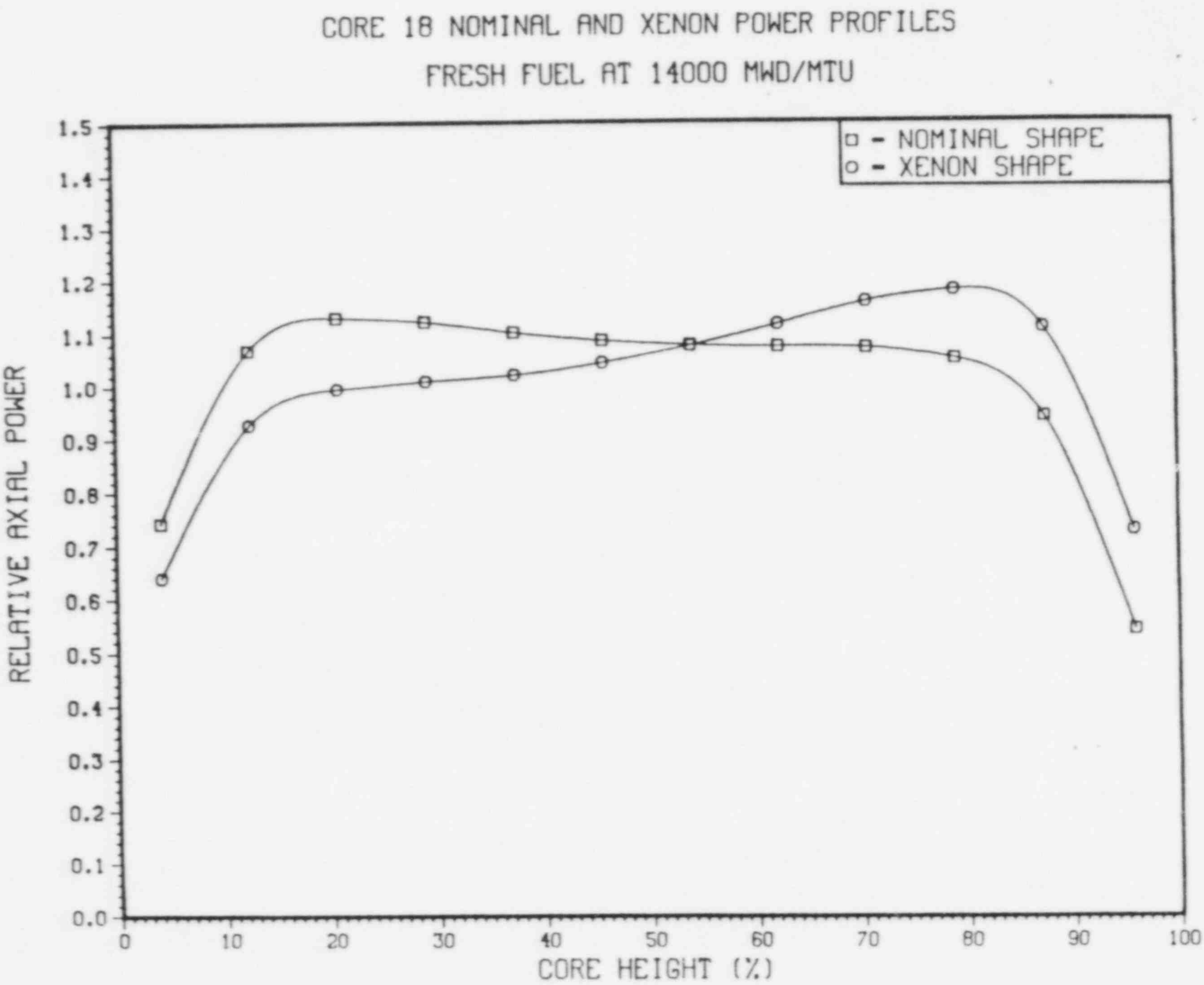
FRESH FUEL AT 1000 MWD/MTU



CORE 18 NOMINAL AND XENON POWER SHAPES

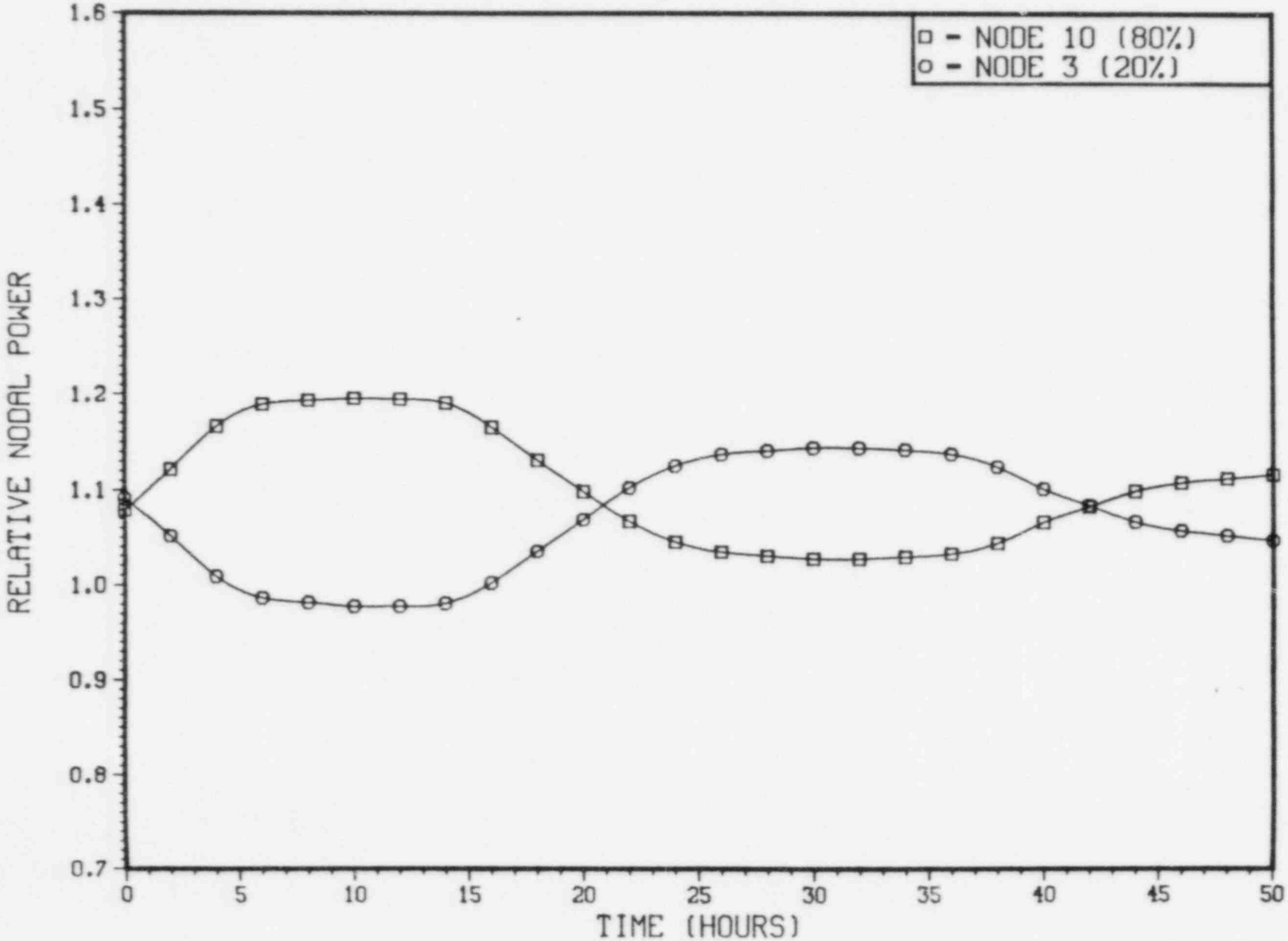
FRESH FUEL AT 6000 MWD/MTU




CORE 18 NOMINAL AND XENON POWER PROFILES
FRESH FUEL AT 14000 MWD/MTU
□ - NOMINAL SHAPE
○ - XENON SHAPE
RELATIVE AXIAL POWER
CORE HEIGHT (%)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100

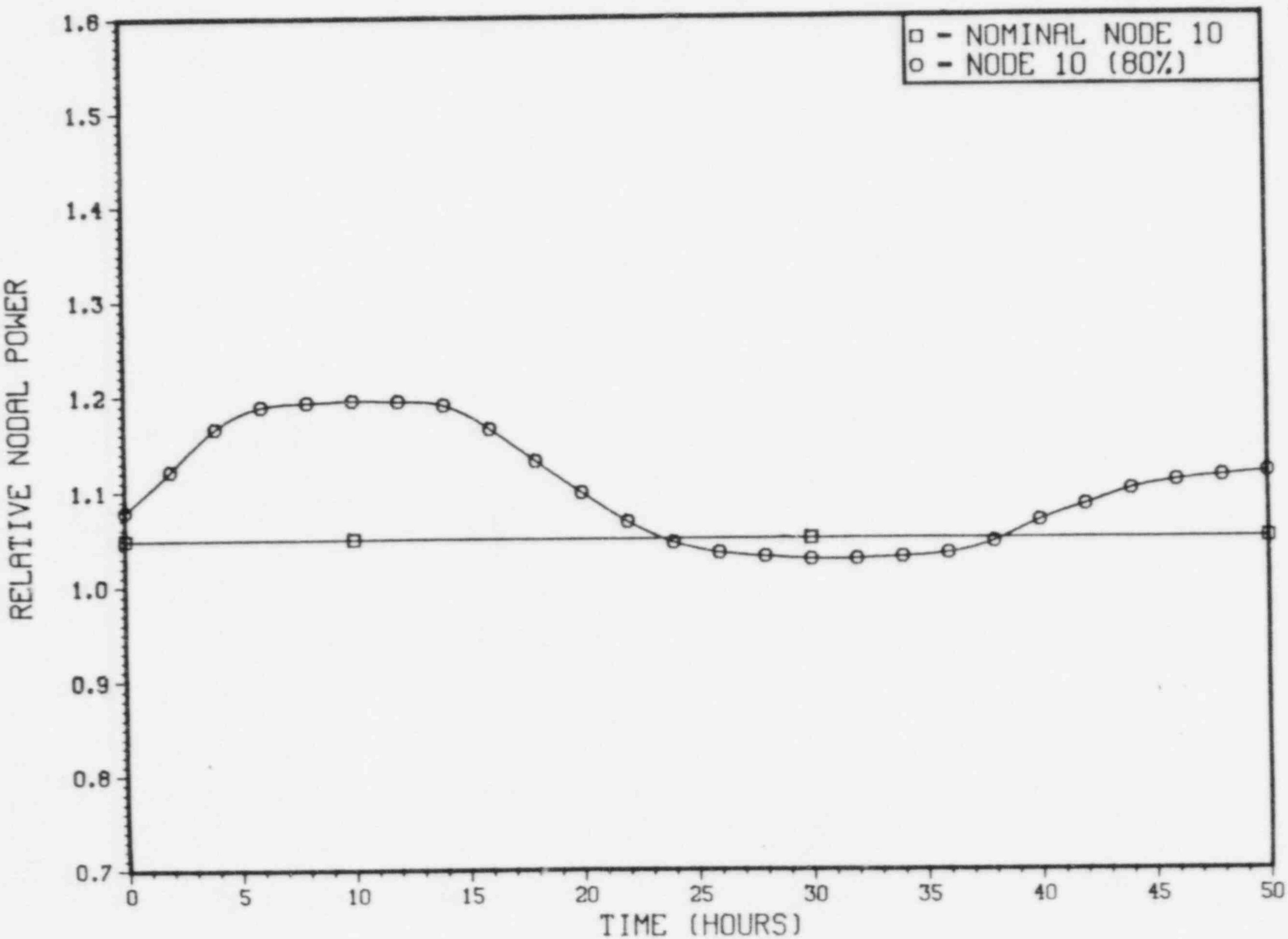
CORE 18 XENON TRANSIENT AT FULL POWER

CORE AVERAGE FOR NODES 10 AND 3



CORE 18 XENON TRANSIENT AT FULL POWER

CORE AVERAGE FOR NODE 10



COMPARISON OF MEASURED VS PREDICTED REACTION RATES
INCORE RUN YR-17-012
1337. MWD/MTU 599.7 MWT. GROUP C AT 83.8 INCHES

	A	B	C	D	E	F	G	H	J	K
1					.890 .887 .433					
2						.981 .987 -.586				
3				1.015 1.011 .396			1.003 .992 1.101			
4			1.011 1.009 .220		1.107 1.097 .886					
5				1.146 1.144 .255				1.093 1.093 .047		
6							1.142 1.136 .518			
7						1.115 1.115 .032		1.019 1.004 1.573		
8							1.018 1.023 -.463			
9			.864 .890 -3.897		.994 1.013 -1.902					
10										

MEASURED
PREDICTED

% DIFF

COMPARISON OF MEASURED VS PREDICTED REACTION RATES
INCORE RUN YR-17-018
6873. MWD/MTU 599.9 MWT. GROUP C AT 82.876 INCHES

	A	B	C	D	E	F	G	H	J	K
1					.891 .897 -.917					
2						.983 1.000 -1.696				
3				1.028 1.020 .790			1.018 1.011 .686			
4			1.024 1.014 1.016		1.104 1.094 .892					
5				1.125 1.125 .008				1.092 1.093 -.067		
6							1.124 1.123 .086			
7						1.102 1.102 .023		1.028 1.012 1.572		
8							1.026 1.024 .238			
9			.663 .680 -2.554		.992 1.005 -1.320					
10										

MEASURED
PREDICTED

% DIFF

COMPARISON OF MEASURED VS PREDICTED REACTION RATES

INCORE RUN YR-17-023

11840.0 MWD/MTU 599.0 MWT. GROUP C AT 82.125 INCH

	A	B	C	D	E	F	G	H	J	K
1					.693 .701 -1.167					
2						.990 1.009 -1.886				
3				1.036 1.031 .664			1.036 1.028 .743			
4			1.034 1.024 1.006		1.101 1.091 .884					
5				1.110 1.107 .282				1.080 1.088 -.707		
6							1.108 1.107 .086			
7						1.094 1.094 .046		1.037 1.024 1.283		
8							1.033 1.030 .304			
9			.654 .662 -1.189		.992 1.004 -1.134					
10										

MEASURED
PREDICTED

% DIFF

COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-013
599.9 MWT. GROUP C AT 85.0 INCHES 1172. MWD/MTU

				0.605 0.614 -1.455					
					1.064 1.079 -1.450				
			1.016 1.029 -1.241			1.034 1.051 -1.663			
		1.031 1.051 -1.901		1.100 1.085 1.385					
			1.084 1.063 1.987				1.019 1.024 -0.492		
						1.074 1.063 1.041			
					1.110 1.085 2.311		1.045 1.051 -0.573		
			1.045 1.051 -0.569			1.028 1.029 -0.058			
		0.662 0.646 2.446		1.084 1.079 0.404					

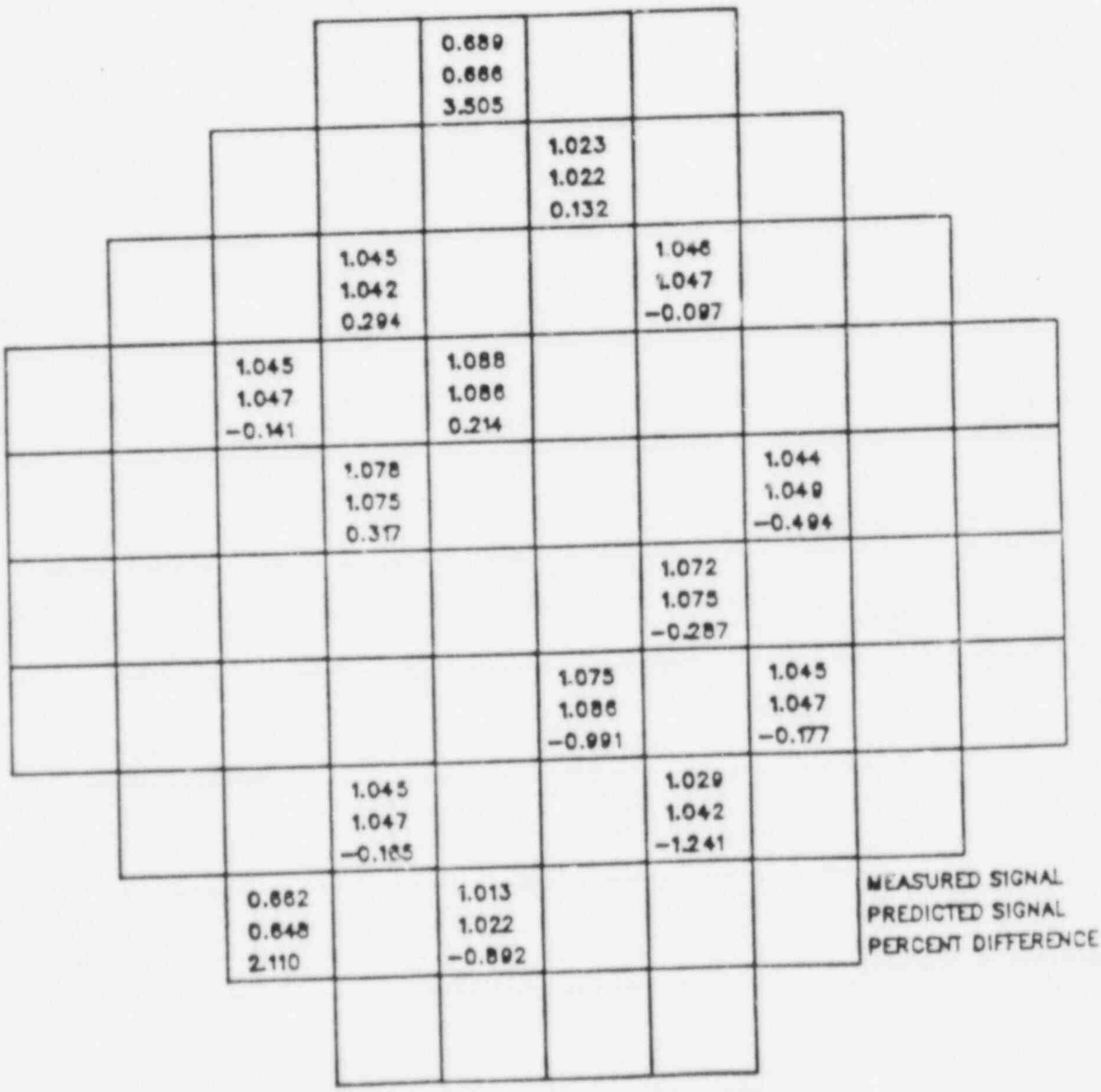
MEASURED SIGNAL
PREDICTED SIGNAL
PERCENT DIFFERENCE

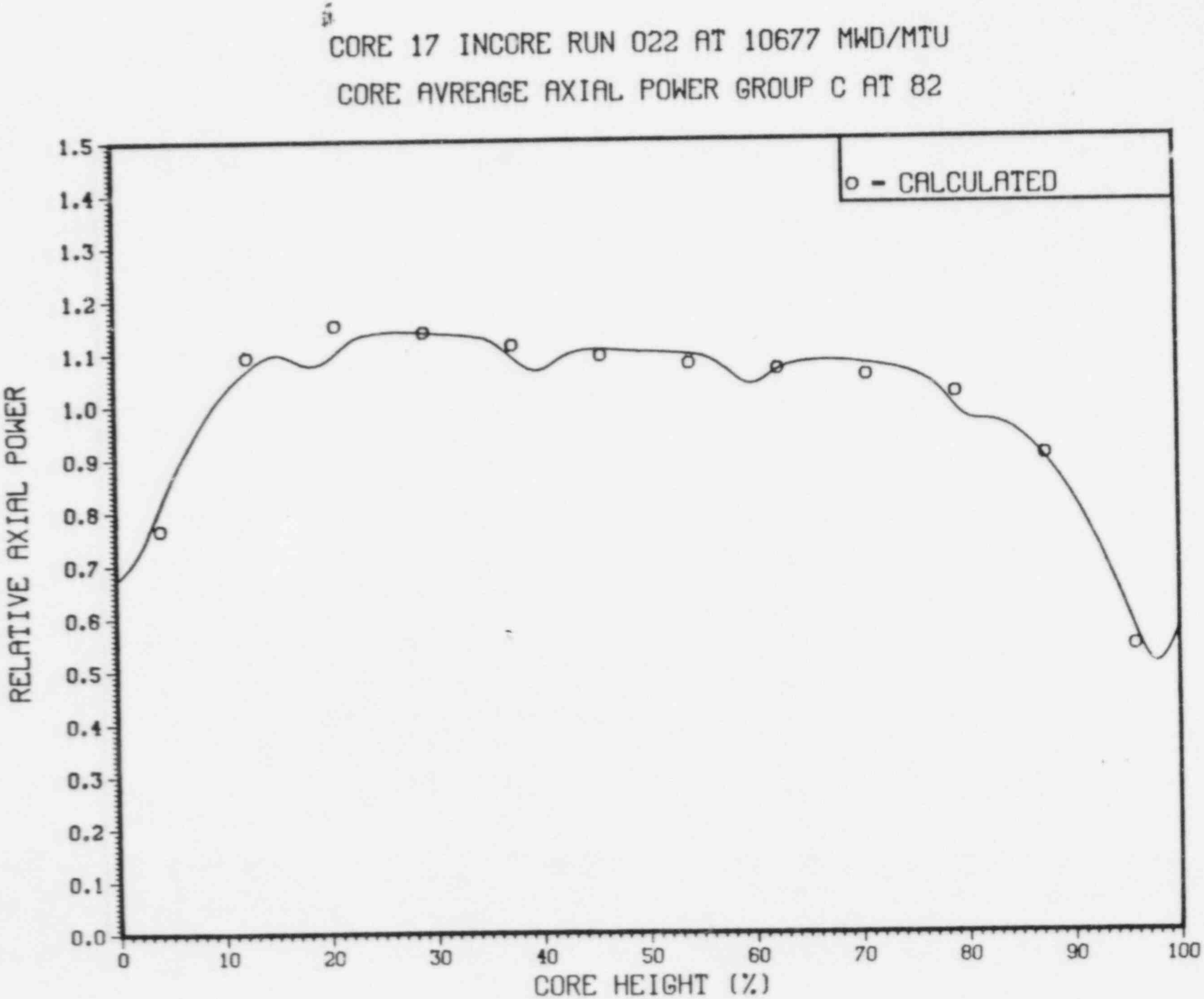
COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-025
599.9 MWT. GROUP C AT 84.6 INCHES 6492. MWD/MTU

				0.645 0.645 0.039					
					1.030 1.042 -1.188				
			1.038 1.037 0.148			1.042 1.047 -0.478			
		1.040 1.047 -0.691		1.090 1.089 0.092					
			1.077 1.073 0.391				1.040 1.040 0.020		
						1.075 1.073 0.196			
					1.090 1.089 0.133		1.051 1.047 0.393		
			1.042 1.047 -0.487			1.033 1.037 -0.293			
		0.868 0.845 3.046		1.040 1.042 -0.171					

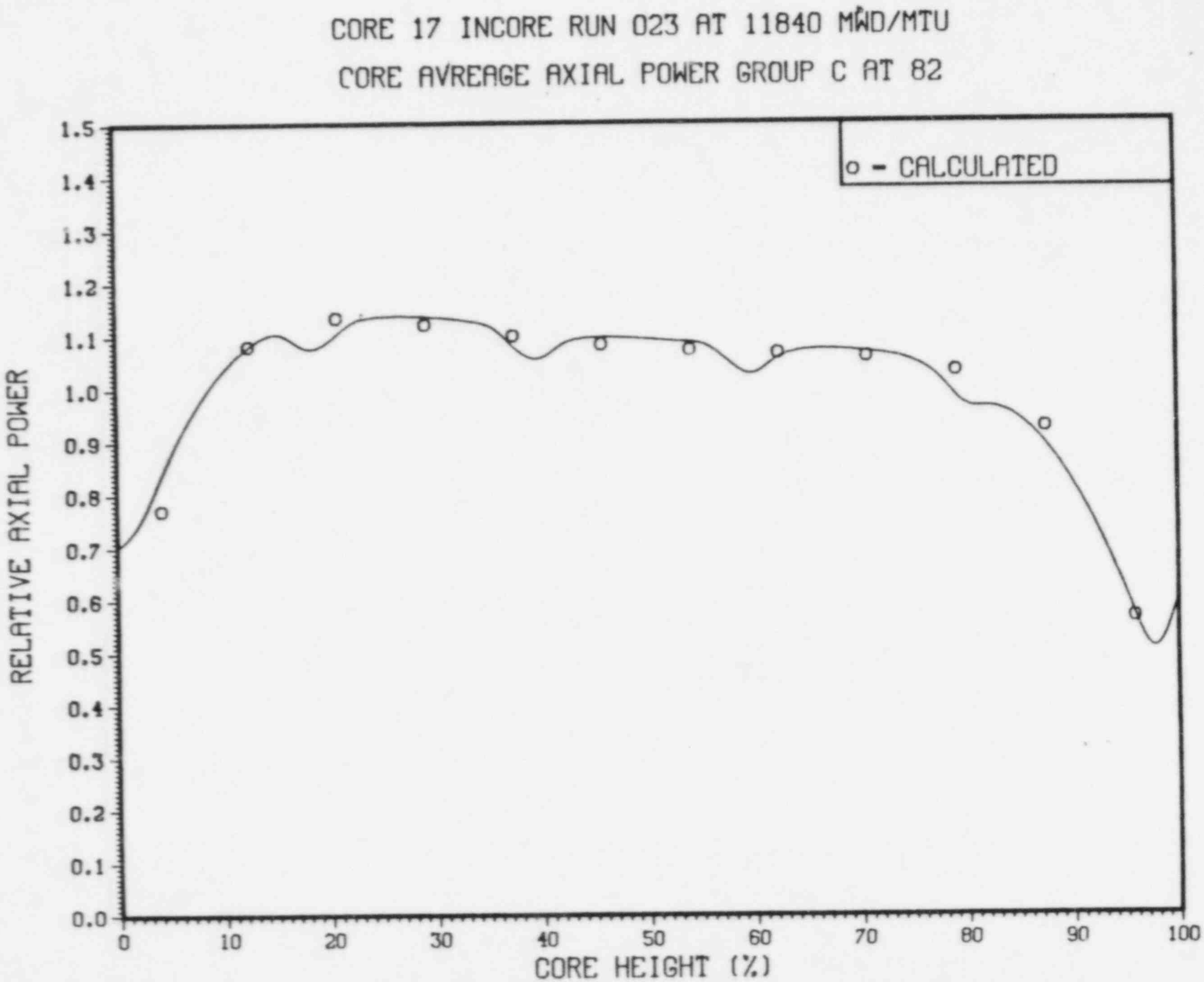
MEASURED SIGNAL
PREDICTED SIGNAL
PERCENT DIFFERENCE

COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-035
599.8 MWT. GROUP C AT 85.6 INCHES 12420. MWD/MTU




CORE 17 INCORE RUN 022 AT 10677 MWD/MTU
CORE AVREAGE AXIAL POWER GROUP C AT 82
o - CALCULATED
RELATIVE AXIAL POWER
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)

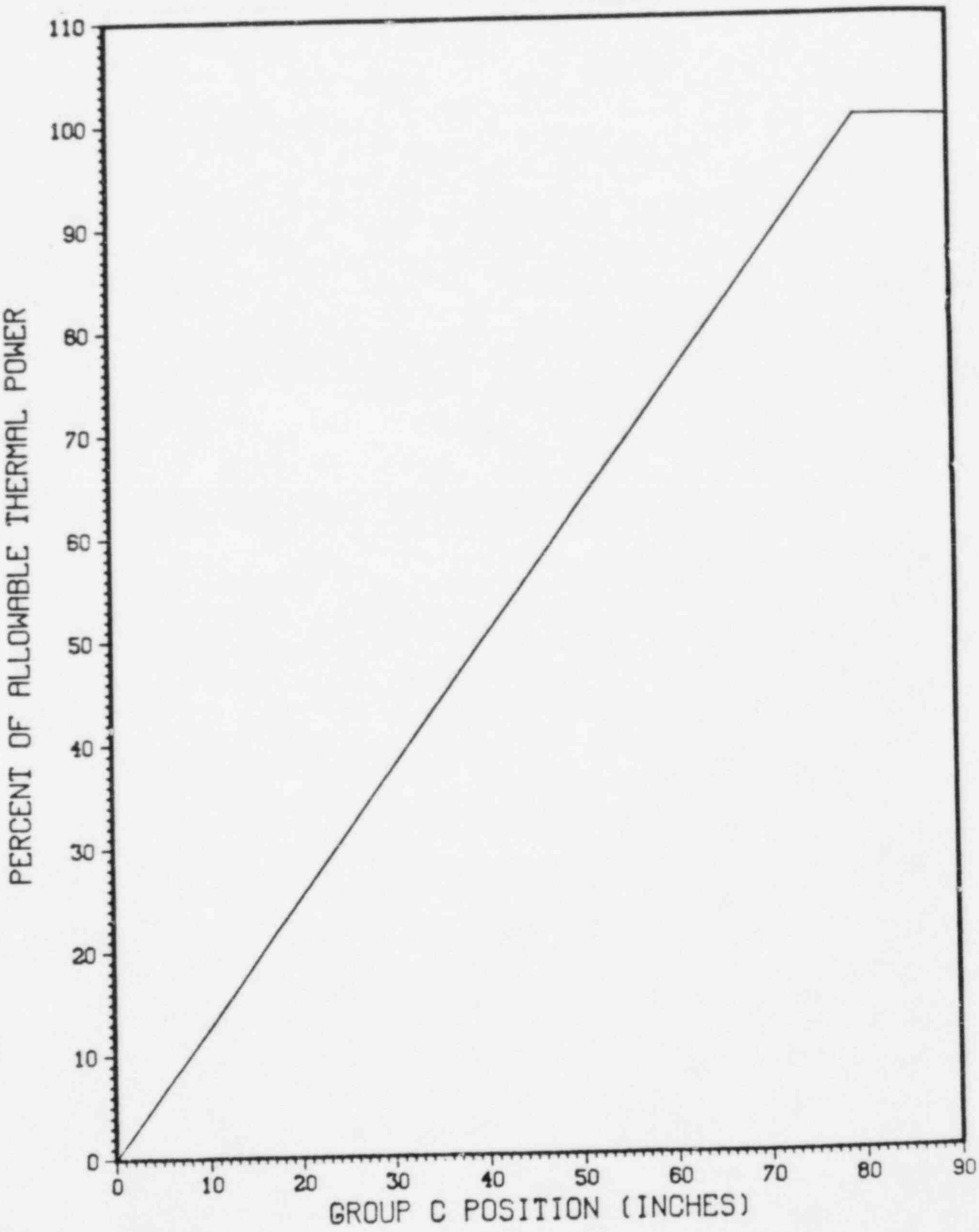
17


CORE 17 INCORE RUN 023 AT 11840 MWD/MTU
CORE AVREAGE AXIAL POWER GROUP C AT 82
o - CALCULATED
RELATIVE AXIAL POWER
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)

18

YANKEE CORE 17

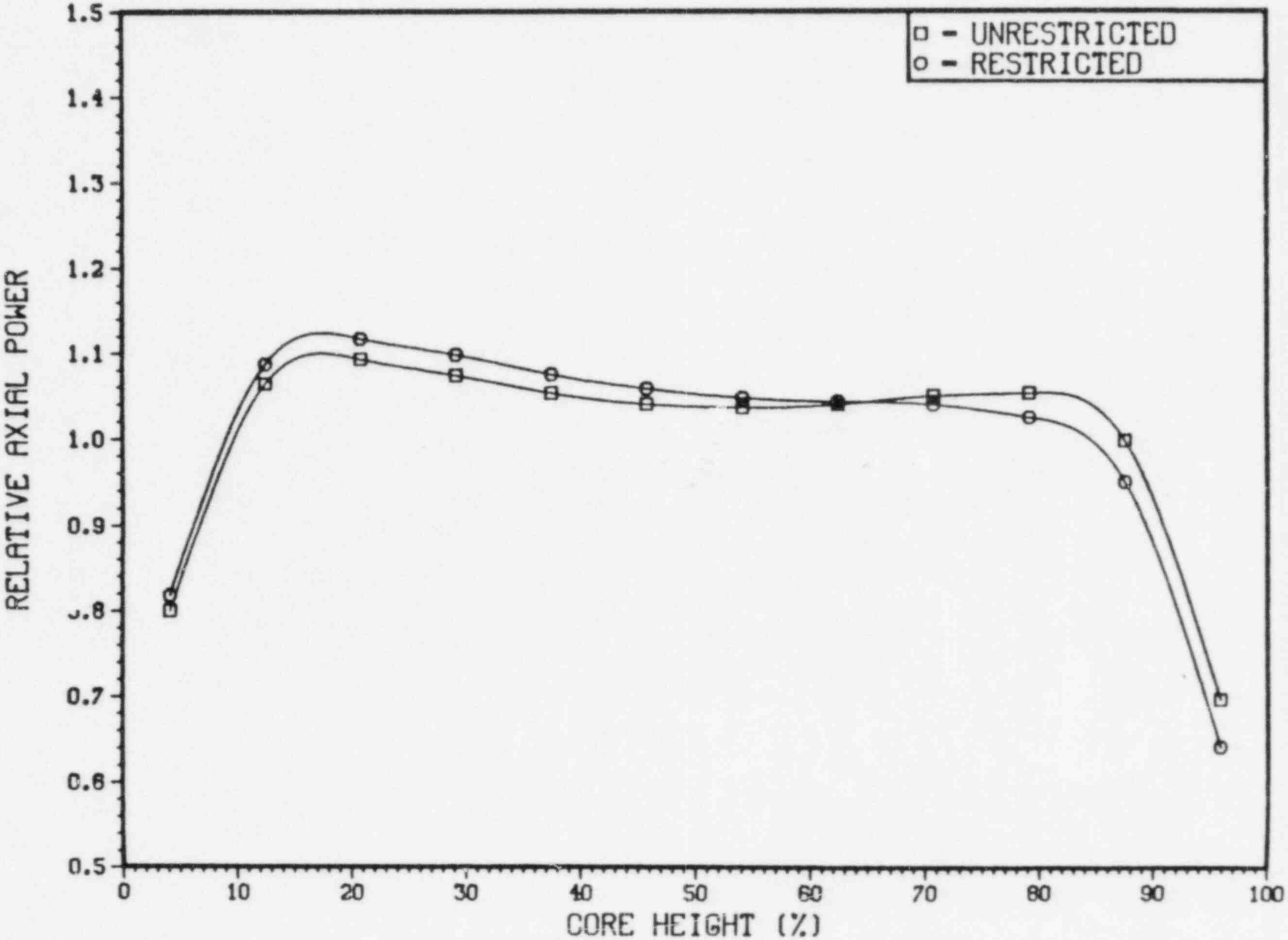
POWER DEPENDENT INSERTION LIMIT



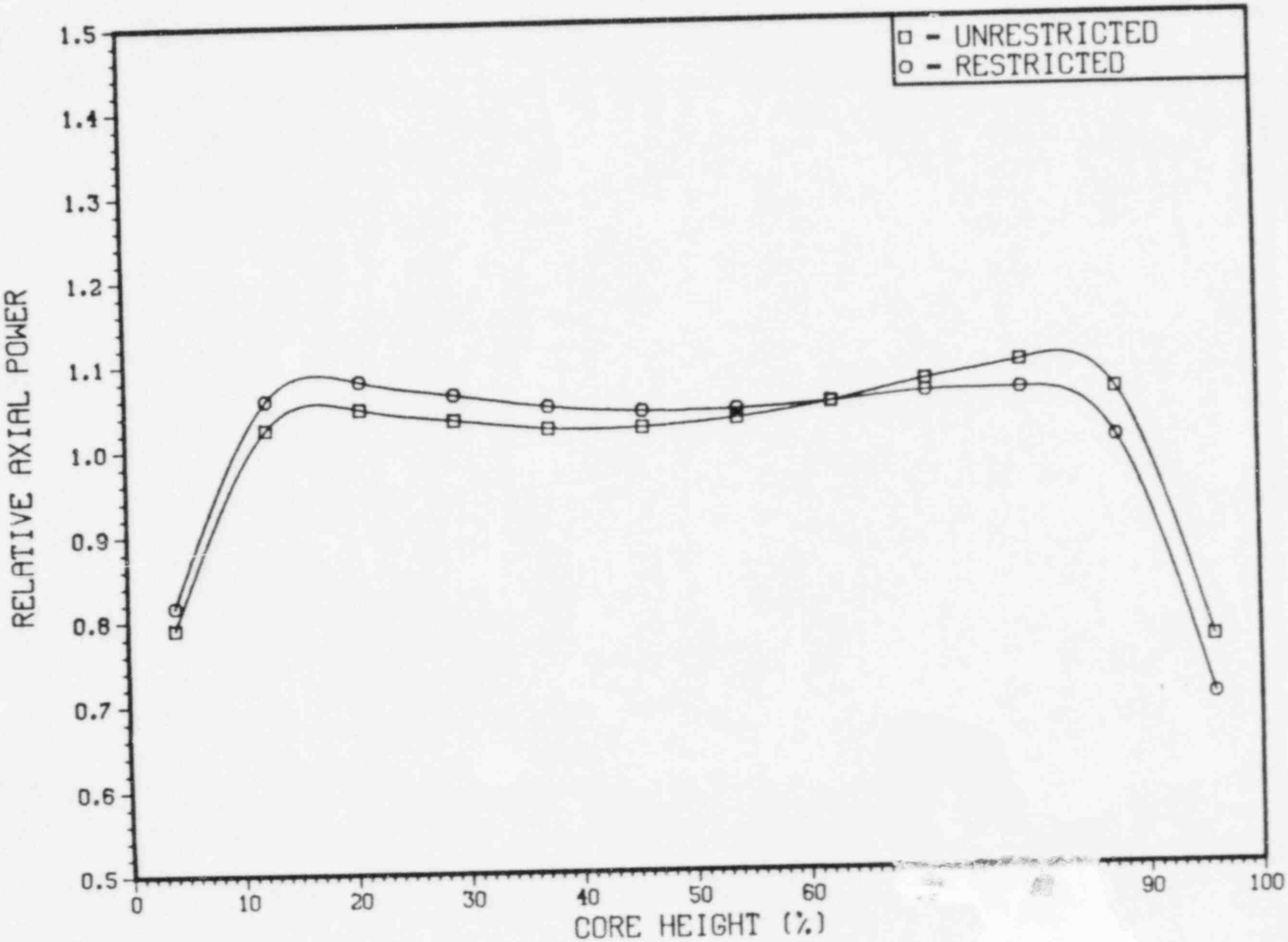
CORE 17 COMPARISON OF AXIAL PROFILES

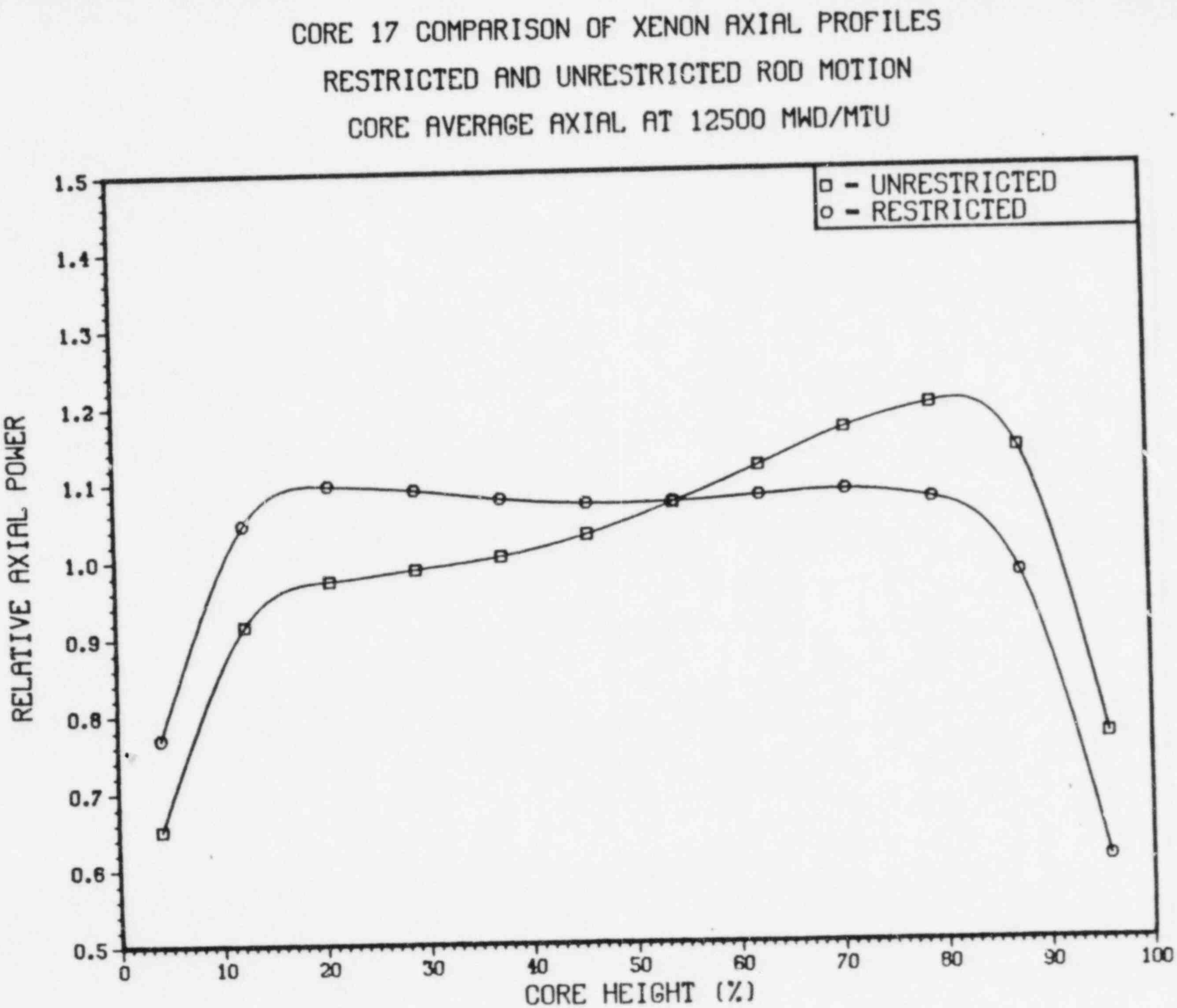
RESTRICTED AND UNRESTRICTED ROD MOTION

BURNED FUEL AT 10000 MWD/MTU



CORE 17 COMPARISON OF AXIAL PROFILES
RESTRICTED AND UNRESTRICTED ROD MOTION
BURNED FUEL AT 12500 MWD/MTU



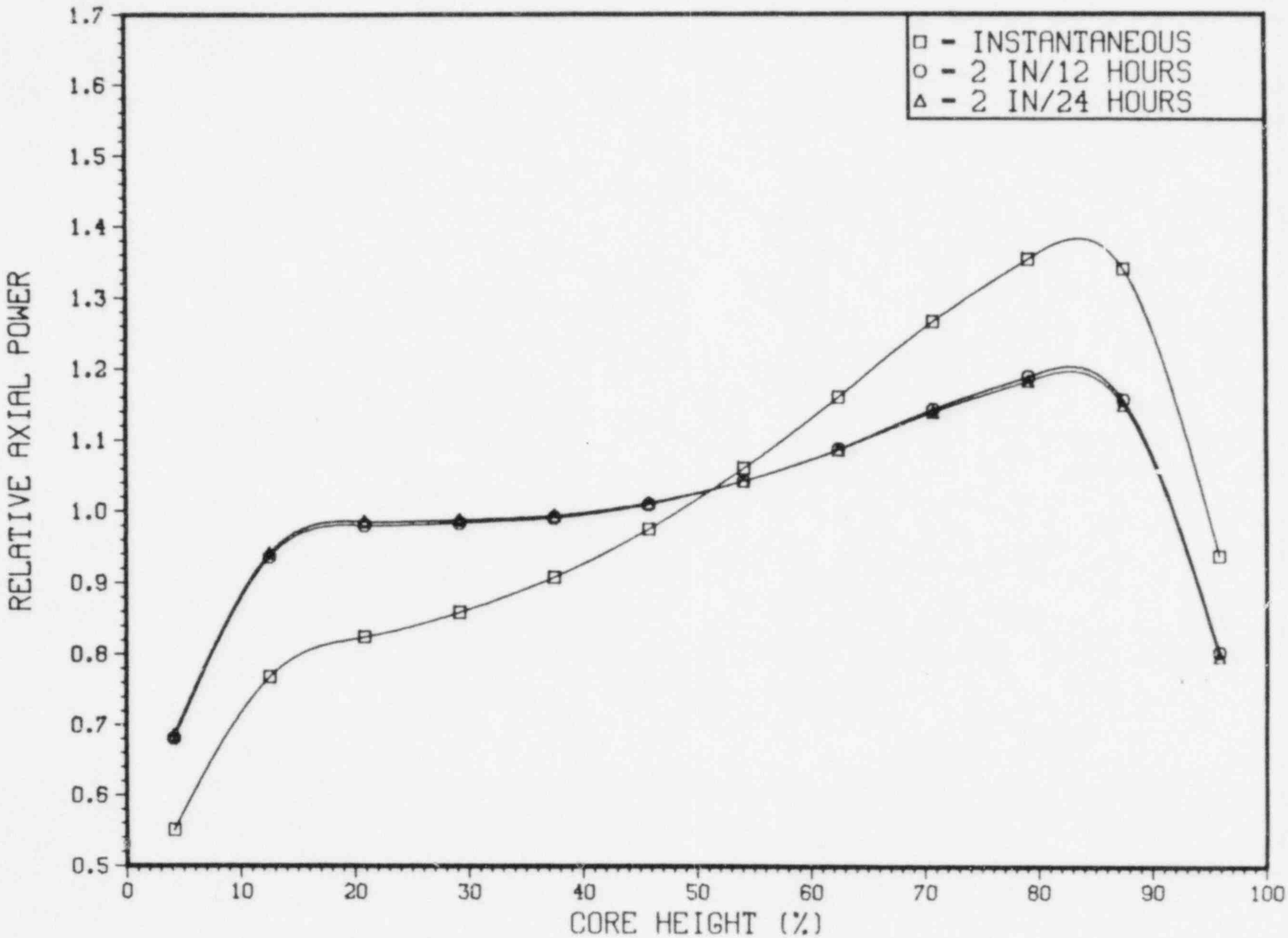

CORE 17 COMPARISON OF XENON AXIAL PROFILES
RESTRICTED AND UNRESTRICTED ROD MOTION
CORE AVERAGE AXIAL AT 12500 MWD/MTU
□ - UNRESTRICTED
○ - RESTRICTED
RELATIVE AXIAL POWER
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100
CORE HEIGHT (%)

22

CORE 17 COMPARISON OF AXIAL PROFILES

RESTRICTED AND UNRESTRICTED ROD MOTION

CORE AVERAGE AXIAL AT 85 % POWER IN COASTDOWN



23

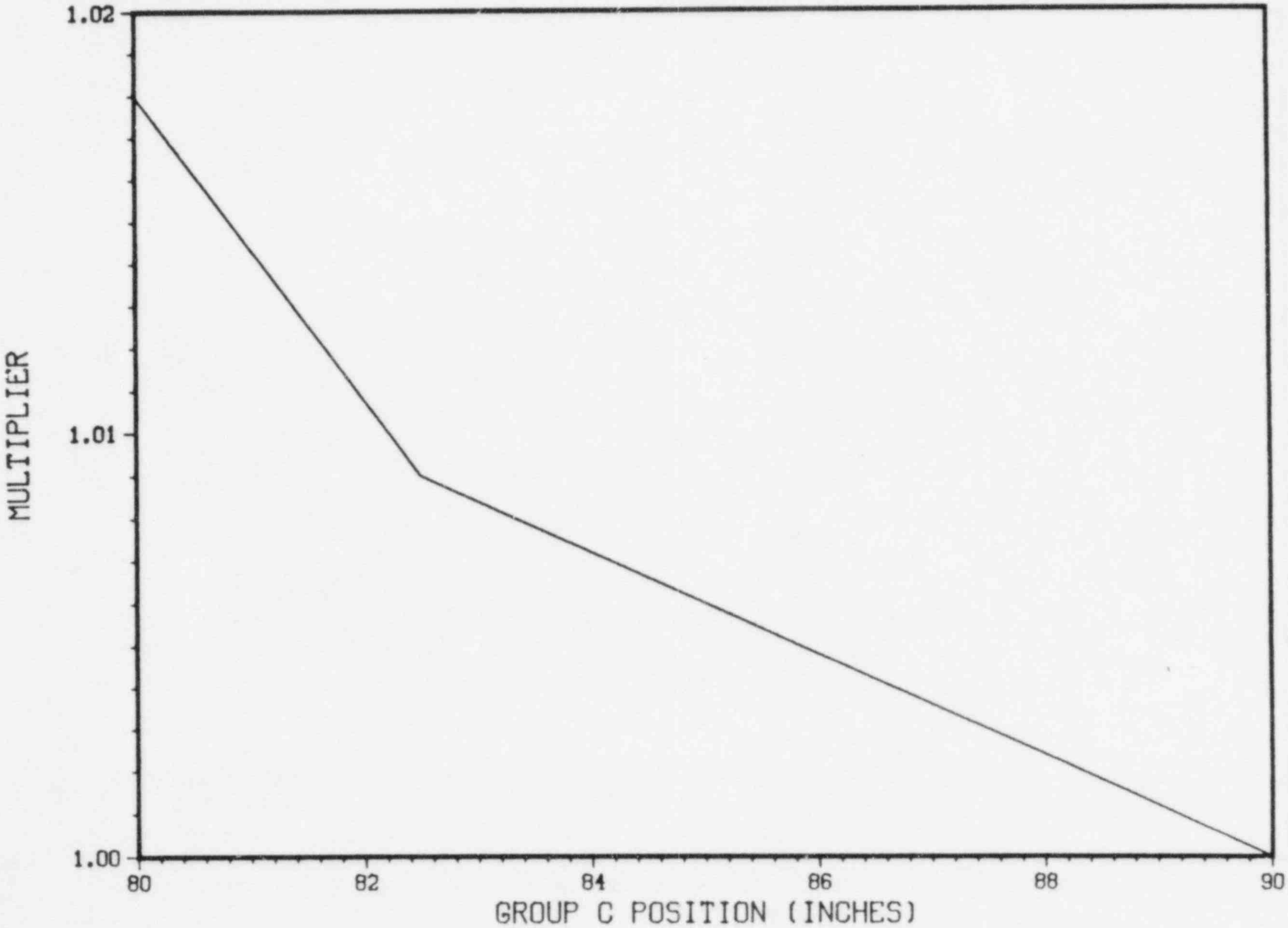
POWER DISTRIBUTION LIMITS TECHNICAL SPECIFICATION

$$\ell_{MAX} = F_{XY} F_Z F_U F_{SS} F_P F_E F_I F_{XE} \bar{\ell}$$

F_{XY}	RADIAL POWER
F_Z	AXIAL PEAK -TO- AVERAGE
F_U	MEASUREMENT UNCERTAINTY (1.068)
F_{SS}	STACK SHORTENING (1.009)
F_P	POWER UNCERTAINTY (1.03)
F_E	ENGINEERING FACTOR (1.04)
F_I	ROD INSERTION FACTOR
F_{XE}	XENON REDISTRIBUTION FACTOR
$\bar{\ell}$	AVERAGE KW/FT

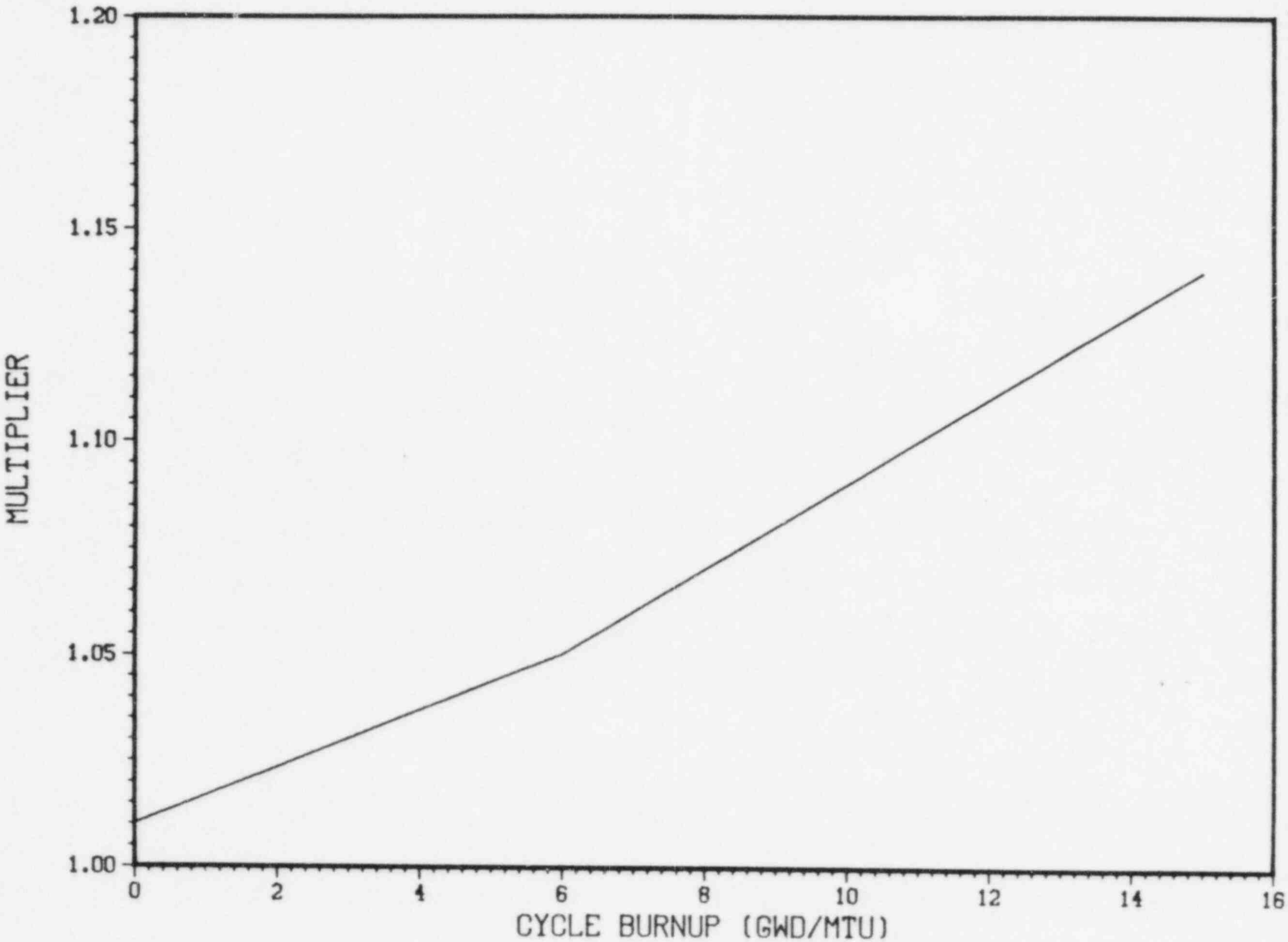
YANKEE CORE 17

CONTROL ROD INSERTION MULTIPLIER



YANKEE CORE 17

MULTIPLIER FOR XENON REDISTRIBUTION



STATISTICAL COMBINATION

F_U MEASUREMENT UNCERTAINTY (1.068)

F_P POWER UNCERTAINTY (1.03)

F_E ENGINEERING FACTOR (1.04)

MULTIPLICITIVE (1.144)

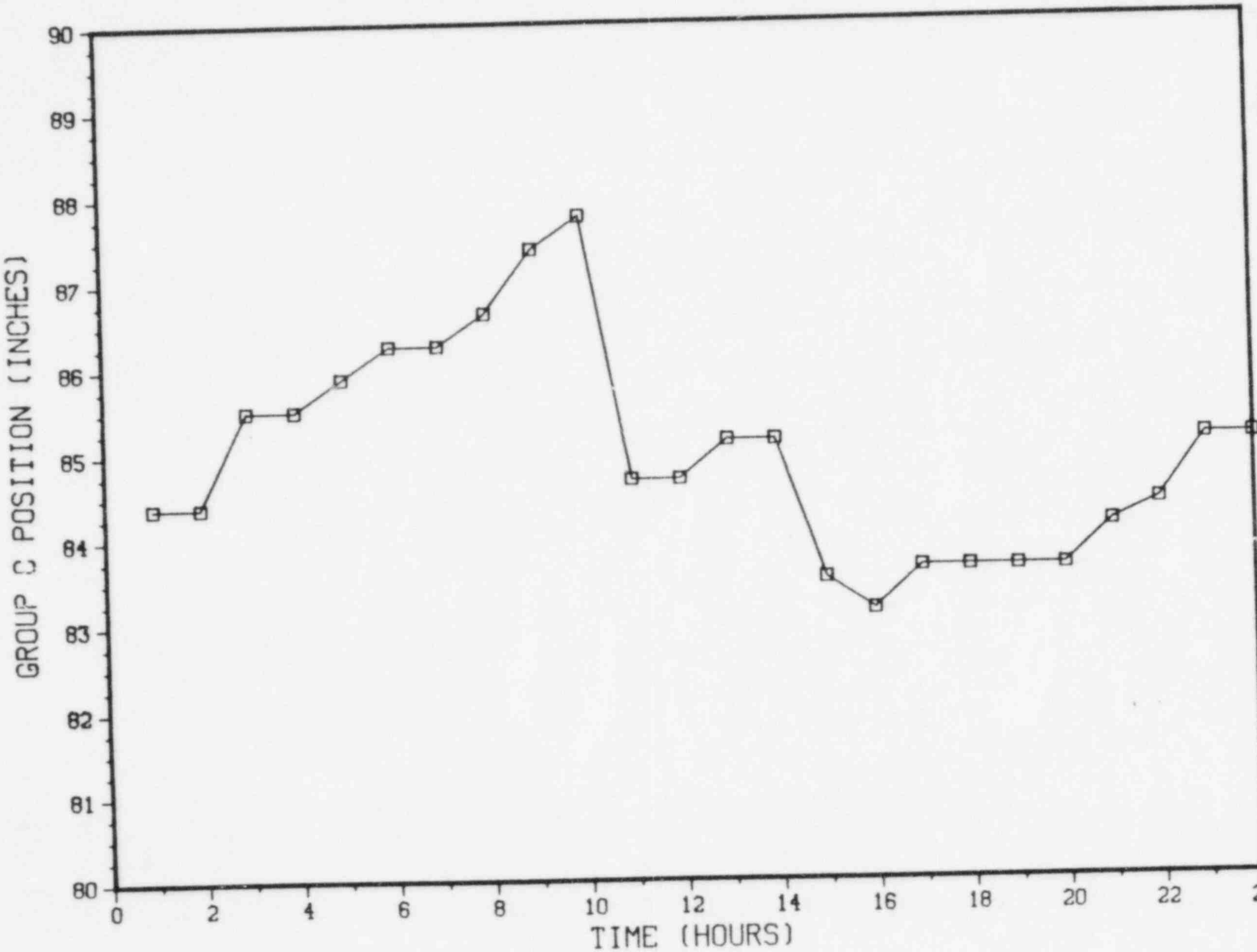
STATISTICAL (1.084)

CORE 18
BASIS FOR POWER SHAPE

NOMINAL

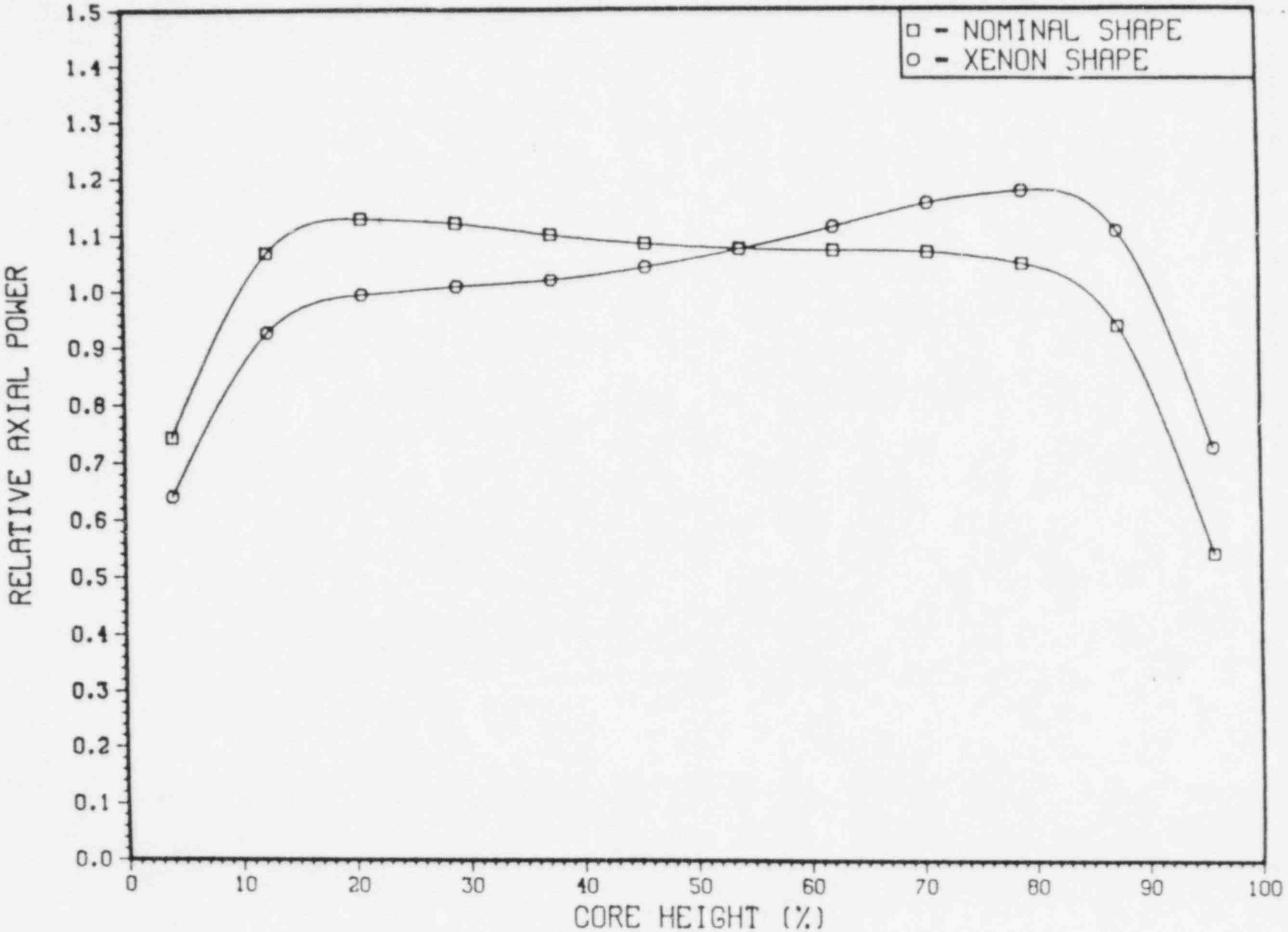
XENON INDUCED

CORE 17 TYPICAL ROD MANEUVERS
STEADY STATE FULL POWER OPERATION



CORE 18 NOMINAL AND XENON POWER PROFILES

FRESH FUEL AT 14000 MWD/MTU



30

YANKEE LOCA METHODOLOGY

ORIGINAL

- 0 XN-75-41 VOLUMES I TO III AND SUPPLEMENTS 1 TO 7
- 0 GENERIC SER ON H B ROBINSON SEPTEMBER 11, 1975
- 0 YR SAMPLE PROBLEM XN-75-41 APPENDIX C
  CHOPPED COSINE POWER SHAPE USED
- 0 YR SER DECEMBER 4, 1975
  - APPLICABILITY OF GENERIC METHOD
  - SPECIAL REVIEW OF SHORTER CORE, THINNER FUEL ROD, DIFFERENT ACCUMULATOR CONFIGURATION
  - GENERIC MODEL CONSERVATIVELY COVERED

MODEL CHANGES AT YAEC

- 0 REVISED CALCULATION OF EOBY 3/77
- 0 LOW FLOW FILM BOILING HTC 6/77
- 0 CORE FLOOD RATE STABILIZATION 7/77
- 0 LOWER PLENUM PHASE SEPARATION MODEL 11/80
- 0 RELAP5YA METHOD DEVELOPMENT (IN PROGRESS)

Axial Power Shape Discussions

0 March 29, 1985 (Call from NRC)

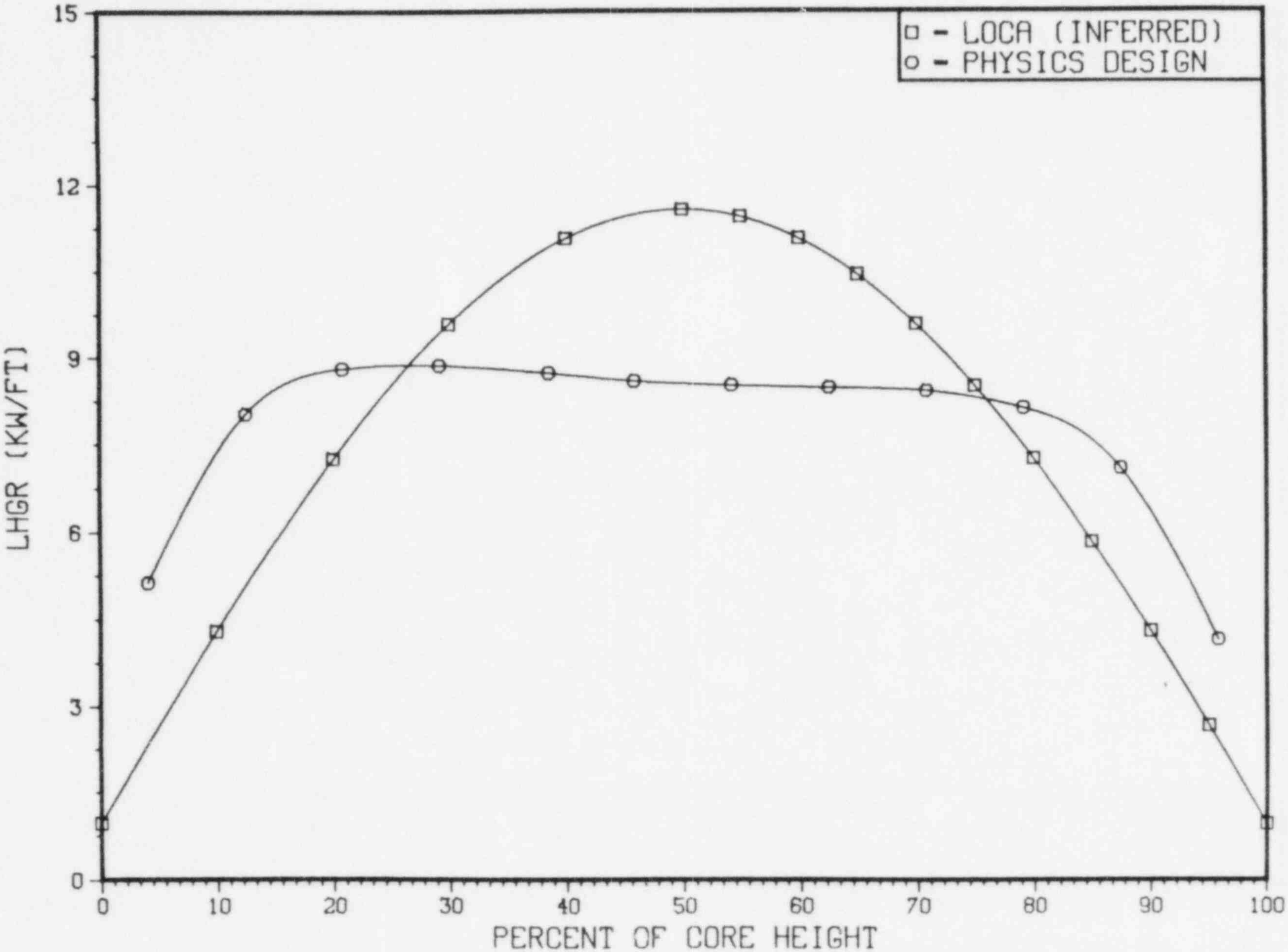
- EXXON Concerns Applicable to Yankee Plant
- YP Uses Cosine Power Shape
- Yankee Will Assess Power Shape Impact

0 April 9 ~~1~~5, 1985 (Call from Yankee)

- Actual Power Shape Flat at EOC
- Actual Peak 8.2 KW/ft; Analyzed Peak 11.2 KW/ft
- At 80% Elevation; Actual KW/ft > Analyzed KW/ft
- Existing Cosine TOODEE-2 Run Reanalyzed With Actual Power Shapes at Higher Elevations.
- PCT < 2200^{o}F
- NRC to call back for more information, if needed.

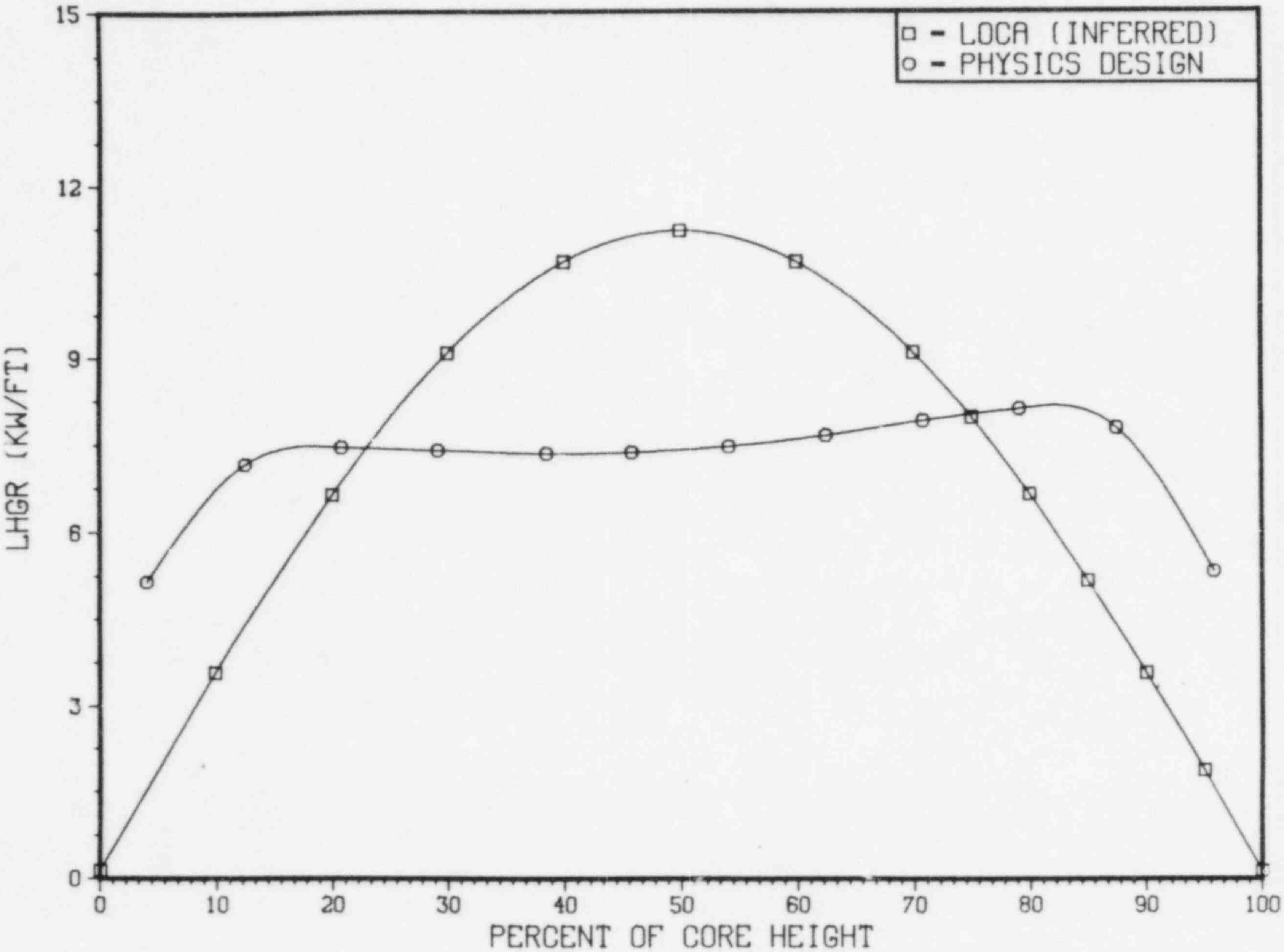
YANKEE CORE 17 AXIAL SHAPE COMPARISON

HOT FULL POWER, 8000 MWD/MTU



YANKEE CORE 17 AXIAL SHAPE COMPARISON

HOT FULL POWER, 12500 MWD/MTU



Cycle 17 Reanalysis Activities

Full Power Operation

- 0 Xe Induced Top Skew Power Shapes May Lead to Derate
- 0 Existing Licensing Analyses Will Cover Bottom Skewed Power Shapes
- 0 Rodded Operation Will Force Bottom Skewed Power Shapes
- 0 Plant Was Ordered to Insert Rods (80" to 83")
- 0 Bottom Peak With Tech.Spec. Limit of 11.2 KW/ft Was Analyzed
- 0 PCT $< 2200^0$F

Power Coast Down Analysis

- 0 Rod Withdrawal Beyond 83" Required

- 0 PCT < 2200°F, if
  - Power ≤ 85%
  - Rod Withdrawal Rate ≤ 2" per day

INJECTION ΔP PENALTY

0 CURRENT MODEL (BASED ON XN-75-41)

ANGLE OF INJECTION	ΔP PENALTY WITH ACC.	ΔP PENALTY WITH PUMP
90^0	1.8	0.8
75^0	1.5	0.35
60^0	0.4	0.35
45^0	0.6	0.30

0 XN-NF-78-30 MODEL

- BASED ON 1/14 AND 1/3 SCALE TEST
- ΔP = 0.15 PSID
- GENERIC APPROVAL SER 3/30/79

0 ΔP = 0.15 PSID APPLICABLE TO YP

Cycle 18 Analysis

Want

- Avoid Power Derate
- Avoid Unwarranted Operating Restrictions
- SER Before Planned Plant Startup

Need

- Near Term Model Changes
    - Injection ΔP Penalty
    - Statistical Combination of Uncertainties
- Use of Nominal Power Shapes
- Change in F_{XE} and F_I Tech. Spec.

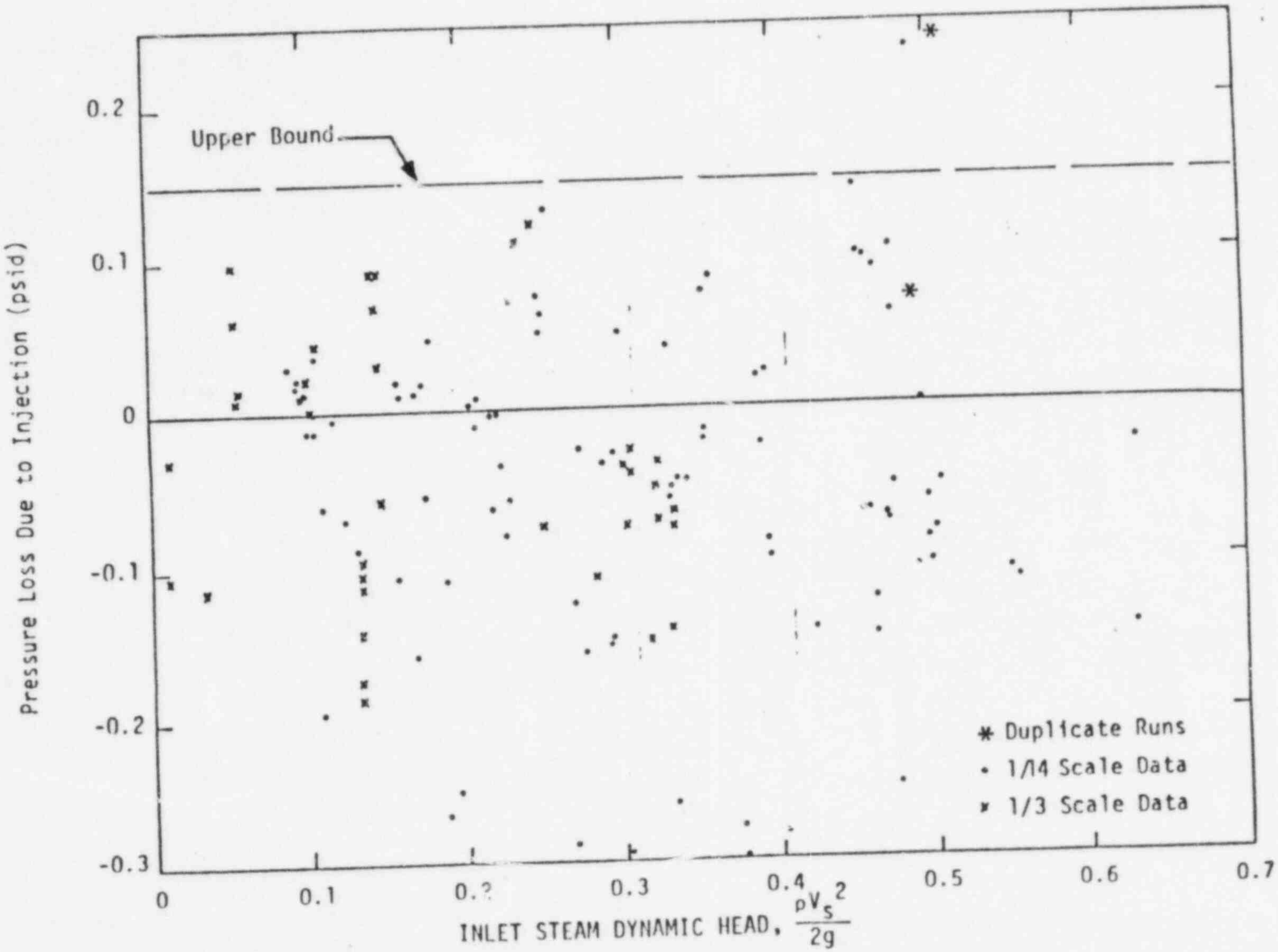


FIGURE 2.3 PRESSURE LOSS DUE TO PUMPED SAFETY INJECTION

OCT 22 1985

The meeting was adjourned. The staff took special note of the forthright approach presented by the licensee in this meeting, and also noted the sound and timely technical efforts that have been expended by the licensee in its investigations of the LOCA model.

Original signed by

James W. Clifford, Project Manager
Operating Reactors Branch No. 5

Enclosures:
1. List of Attendees
2. Meeting Agenda
3. Core Power Distribution Handouts
4. LOCA Analysis Methods Handouts

cc w/enclosures:
See next page

DISTRIBUTION
Docket File
ORB#5 Rdg
CJamerson
JClifford
JZwolinski
NRC PDR
Local PDR
OELD
EJordan
BGrimes
ACRS(10)
NRC Participants

DL:ORB#5	DL:ORB#5	DL:ORB#5
CJamerson	JClifford:tm	JZwolinski
10/21/85	10/16/85	10/22/85

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 22, 1985

Docket No. 50-29

LICENSEE: Yankee Atomic Electric Company

FACILITY: Yankee Nuclear Power Station

SUBJECT: MEETING SUMMARY - MEETING WITH YAECO ON ECCS CODE REVISION

A meeting was held between Yankee Atomic Electric Company (YAECo) and the NRC staff to discuss proposed revisions to the ECCS codes and code assumptions for the Yankee plant. The meeting was held in Bethesda, Maryland on August 8, 1985 at the request of YAECo. A list of attendees is provided in Enclosure 1. The meeting agenda and objectives are provided as Enclosure 2.

After a brief introduction by the NRC and YAECo project managers, the licensee provided discussions regarding the reasons for the current reevaluation of the Yankee ECCS codes, the Yankee plant characteristics, the core flux shapes and associated uncertainties, the history of the Yankee ECCS code development, and proposals for modifying the ECCS codes and input assumptions to assure continued compliance with 10 CFR 50.46. A more detailed discussion of each of these presentations is provided in the following paragraphs. The handouts used for these presentations are provided in Enclosures 3 and 4.

In its introduction, the licensee explained that it was informed in the Spring of 1985 that the axial power shapes it had been using for ECCS analyses may no longer be acceptable to the NRC staff. Specifically, the cosine shaped axial power shape had been questioned. The licensee explained that it had taken action to limit flux in the upper core region by operating with a rodded core which ensured a bottom-peaked power distribution. This provided assurance that Yankee remained in compliance with 10 CFR 50.46 while the ECCS analysis methods were being reviewed. The desirability of operating the Yankee core in a rodded condition was discussed, since this is not the normal operating mode for Yankee. The licensee and the staff also discussed the likelihood that the staff's concern for compliance with 10 CFR 50.46 was not a safety issue due to the conservatisms that the licensee felt existed in the Yankee ECCS codes. A more detailed discussion of the code conservatisms was provided by Yankee later in the meeting.

The licensee provided a discussion on the Yankee core power distributions (Enclosure 3). Following a description of the plant characteristics, the licensee described its calculated flux distributions for Cycle 18 (Enclosure 3, pages 5-8). The graphs show nominal flux distributions for various times in core life, and show the effects of xenon on the flux

distributions. As shown on page 8 of Enclosure 3, the calculated xenon transient induces a top-peaked power distribution late in core life. In response to a staff question, the licensee explained that load-following calculations for xenon transient evaluation were performed at full-power steady state conditions, with Technical Specification (TS) limits that require the plant to be held at a reduced power following a power transient to limit the effects of the xenon transients if the rods are outside the rod insertion limit shown on pages 3 and 19 of this enclosure. The licensee then described the self-damping characteristics of the xenon transient following a rod-induced power transient (Enclosure 3, pages 9 and 10).

The licensee then provided the NRC staff with a comparison of actual measured flux levels against calculated levels to show that the current codes estimate flux levels within approximately 1%, except at the outermost regions of the core. The comparison was provided for the current and previous cores (cores 17 and 16). Graphs of calculated versus actual axial flux distributions are provided on pages 17 and 18 of Enclosure 3, which show a close comparison between calculated and actual axial flux.

The licensee provided a discussion of the administrative controls currently in place at Yankee to provide assurance that the requirements of 10 CFR 50.46 are met with the current code for Cycle 17. The licensee has added administrative controls to limit control rod movement which limits power levels in the upper core region to limit any top peaked power distribution. In addition, current TS have a restriction on how soon after a power reduction the core can be returned to full power if the rod heights are outside the rod insertion limit, and there is a restriction on rod reactivity transient rates. Both of these TS restrictions serve to limit the effect of xenon transients on the axial flux distribution. The licensee has stated that the additional restriction on rod withdrawal limits will remain in effect until reaching 80% power during the power coastdown. Compensation for xenon transients will be accomplished using boron, to keep the rods within the administrative restriction.

To show the effects of operating with a rodded core, graphs were provided showing the axial flux distribution with and without the rod restriction, at two times in core life (page 20, 21, Enclosure 3). Page 22 (Enclosure 3) shows the effect on xenon transients with and without the rod restriction. The graphs point out that the flux distribution is bottom-peaked with the rodded core, which has the plant within the original analysis assumptions for cycle 17 operations. The graph on page 23 (Enclosure 3) further shows the effect of reactivity rates on the axial power distribution, which points to the reason for maintaining the TS limits on reactivity rates.

The licensee then provided information regarding the conservatisms in the LOCA limits of Linear Heat Generation Rate (LHGR) vs. core burnup. The licensee presented information regarding conservatisms that exist in the Xenon Redistribution Factor (Fxe) and the Rod Insertion Factor (Fi). The licensee also discussed three other factors (the Measurement Uncertainty (Fu), the Power Uncertainty (Fp), and the Engineering Factor (Fe)) in the TS LHGR limit. The licensee proposes to combine these three factors statistically, as opposed to the current method of combining them multiplicatively, as discussed on page 27 of Enclosure 3. The NRC staff

stated its belief that based on the information presented in the meeting, statistically combining the three factors (Fu, Fp, and Fe) should be acceptable. The NRC staff stated that the licensee should provide its justification for this proposal to allow for NRC staff review.

The next three slides (pages 28-30, Enclosure 3) show information regarding the integration of boron dilution with control rod motion, to support the Yankee proposal to use nominal flux shapes in its calculations, as opposed to the current approach of using the xenon-induced flux shapes. The slide on page 30 (Enclosure 3) shows the difference in axial flux shapes for the nominal and xenon shapes, and shows a bottom-peaked power distribution for the nominal case, and a top-peaked distribution for the xenon case.

Following the presentation, the NRC staff pointed out that the normal analysis assumptions consider TS allowable transients (i.e., if TS allow rod motion between 80-90 inches, the analysis should use these limits). In addition, the NRC staff stated that administrative controls may not be appropriate, but that the TS should be modified appropriately. The licensee provided the argument that the nominal approach is more like the way the plant operates, and therefore should be used for the calculations. The NRC restated its position of using the limiting analysis for the licensing basis. On the issue of using a statistical combination of the uncertainties, the NRC staff stated that similar proposals from other licensees have been accepted, while others have not, on the merits of the individual cases. The NRC staff would need to look at the details of the Yankee proposal. The NRC staff stated that the information to be provided by the licensee needed to include an appropriate data base, and to show independence of the factors involved. Based on the information presented at the meeting, the NRC staff felt that the Yankee approach to statistical combination of uncertainties was appropriate, but that the staff would have to see the specifics before making its final determination.

The NRC staff then questioned the licensee regarding plans for removing Fi and Fxe from the LHGR calculations. The licensee felt that a bottom shaped flux distribution bounded the cosine curve, and Fi would not be needed in the calculation. In the consideration for Fxe, the current TS value for Fxe would be modified as a part of the cycle 18 reload submittal, and the licensee is considering other restrictions (e.g., rod motion limits) that may eliminate the need for Fxe. As part of the reload submittal, the licensee intends to make a case for eliminating the Fxe bottom mutiplier (page 26 of Enclosure 3).

The licensee presented information related to the LOCA analysis methods that are being investigated (Enclosure 4). The licensee explained the history behind the previous analyses performed up through cycle 17. The analysis for cycle 18 had been performed using the cosine shaped flux distribution, and the licensee explained that the calculations would need to be re-performed based on the current NRC concerns. To complete the reanalysis, the models that are currently being used will have to be modified in order to remove the operating rod withdrawal restrictions to allow operation without a rodded core. In 1975, the licensee had identified the Yankee models, explaining the differences between the Yankee model and the generic effort based on the Exxon model being used for the H.B. Robinson plant. Since Yankee was using the cosine-shaped flux

distribution, it used Fi and Fxe mutipliers to add additional conservatism. Since the initial code development, a number of changes have been made to the Yankee model as more knowledge or limitations in codes have been identified. The latest questions regarding the Yankee ECCS codes deal with conditions during the reflood phase of the accident analyses (after the blowdown and refill phases have ended). Based on the current concerns, a composite flux distribution was used to perform the LOCA analyses. The composite distribution included the most limiting of the cosine and the physics-determined flux distributions.

The technical issue of concern in the reflood phase was to not have the flux peak in the upper core region because of the time it took to reflood that region. In the previous analyses using the cosine shaped flux distribution, the flux peak was in the core midplane, and as long as the peak remained below this core midplane, the analysis using the cosine shape would be bounding. The current analysis which identified a top-peaked power distribution led to rod withdrawal restrictions to provide flux suppression in the upper core region to obtain a bottom peaked flux distribution, and therefore make the cosine shaped flux distribution again bound the actual flux distribution. Page 6 of Enclosure 4 shows the licensee's proposed operating restrictions for the power coastdown phase of the operating cycle. This page shows that rod withdrawal above the current restriction of 83 inches will be necessary. To allow for this, the licensee proposed a rod withdrawal rate limit of less than or equal to 2 inches per day to ensure the analysis' peak centerline temperature (PCT) remains less than 2200 degrees post-LOCA.

The licensee then provided a discussion of the cycle 18 analyses that have been performed to date. Page 8 (Enclosure 4) shows the items the licensee is requesting regarding the model and analysis parameter changes for its model. One of the issues shown deals with an injection delta-P penalty, which is a conservatism included in the model to account for pressure loss due to injection parameters of angle and flow rate. The licensee is currently using a 90 degree angle of injection, which results in a delta-P penalty of 0.8 psid. With a modified model, the licensee proposes a delta-P penalty of 0.15 psid. The staff's initial impression is that there should not be any problem in granting a modification of the delta-P penalty, but the staff needs to evaluate the licensee's calculations and assumptions before making a final decision.

The NRC staff questioned the appropriateness of using nominal power shapes in the licensee's calculations. The licensee explained that it intends to perform a series of power shape calculations, which are an extension of burnup sensitivity studies, using calculated flux shapes, not the TS limits. The licensee acknowledged that this approach needs to be justified. The TS would then be based on a calculation to allow operating margin providing for errors in calculations compared to measured flux levels. This extra margin has in past efforts resulted in calculations based on TS kW/ft limits to show possible problems in meeting Appendix K. The licensee had then proposed a single TS limit which would be limiting, or bounding, and be shown to be limiting based on sensitivity studies. The staff pointed out that the licensee's efforts to meet Appendix K would be helped by using a variable limit on the kW/ft limit based on core height.

The licensee explained the differences between its analyses and the Westinghouse methods (which result in a variable kW/ft limits). The licensee explained that to show one kW/ft limit, as opposed to a variable one,

sensitivity studies are needed to show the limit is bounding. The current Yankee kW/ft TS limits are based on cosine-shaped flux distribution calculations. The licensee is working on developing kW/ft TS limits based on a top-peaked flux distribution, and add a known amount of conservatism. for its variable kW/ft limits. Westinghouse uses height-dependent flux (F delta H) limits for departure from nucleate boiling (DNB) and hot channel calculations. These same limits are used in the Westinghouse LOCA calculations. The Yankee model does not use F delta H in its LOCA model. The licensee does not feel there are any radial flux (Fxy) dependencies in the LOCA calculations, and therefore uses kW/ft instead. It was also noted that Westinghouse shows compliance with Appendix K in pre-cycle calculations, while Yankee verifies compliance throughout the cycle using actual measurements to compare to its calculations.

The licensee then explained that if the delta-P penalty modification is approved, there would be no need to benchmark the modified Yankee model, due to the nature of the changes. The licensee also pointed out that this change in its model would be a permanent change. The licensee proposed to provide the changes to the model as a separate enclosure to the reload package. The staff felt it would be more appropriate to provide the LOCA model changes in a separate letter, while at the same time use the modified model in the cycle 18 submittal. The staff felt that Yankee had provided sufficient information in the meeting such that the NRC staff feels the change to the model will be acceptable, pending confirmation of the information provided at the meeting. The licensee stated that if a problem with the cycle 18 analyses or the TS were to occur, the fallback position would be to rely on current TS with rod restrictions.

The licensee stated that as it develops its final proposal, it may ask for additional conference calls or meetings to discuss its approach with the staff. This approach is acceptable to the staff. The licensee was asked to provide a letter of commitment, to include the bases for removing the current rod restrictions, including any additional restrictions that may be necessary during the power coastdown, as discussed earlier in the meeting.

The licensee asked one additional question regarding whether the proposed modifications to the Yankee LOCA model would have to be prenoticed as a license amendment. The staff's position is that the proposed modifications, other than the TS that result from the calculations, are of such a nature that the license is not being modified, and therefore would not require prenoticing.

The resident inspector noted that with the changes in operating restrictions proposed by the licensee, the Licensee Event Report (LER) would need to be modified. The licensee agreed to submit a modified LER.

The meeting was adjourned. The staff took special note of the forthright approach presented by the licensee in this meeting, and also noted the sound and timely technical efforts that have been expended by the licensee in its investigations of the LOCA model.

James W. Clifford

James W. Clifford, Project Manager
Operating Reactors Branch No. 5

Enclosures:
1. List of Attendees
2. Meeting Agenda
3. Core Power Distribution Handouts
4. LOCA Analysis Methods Handouts

cc w/enclosures:
See next page

cc:
Mr. James E. Tribble, President
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Thomas Dignan, Esquire
Ropes and Gray
225 Franklin Street
Boston, Massachusetts 02110

Mr. N. N. St. Laurent
Plant Superintendent
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Chairman
Board of Selectmen
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Resident Inspector
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Regional Administrator, Region I
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Robert M. Hallisey, Director
Radiation Control Program
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Boston, Massachusetts 02111

Mr. George Papanic, Jr.
Senior Project Engineer - Licensing
Yankee Atomic Electric Company
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Framingham, Massachusetts 01701

ENCLOSURE 1

MEETING WITH YAECo RE: ECCS Codes

NAME	AFFILIATION
Jim Clifford	NRC/NRR/DL
John A Zwolinski	NRC/NRR/DL
George Papanic Jr	YAEC
John D. Haseltine	YAEC
Donald Hunter	YAEC
Ausaf Husain	YAEC - LOCA Group
Richard J. Cacciapouti	YAEC - Reactor Physics
Marvin Dunenfeld	NRC/CPB
Howard Richings	" "
Robert Jones	NRC/RSB
Bill Szymczak	YAEC - LOCA Group
Kevin J. Morrissey	YAEC
Bruce C. Slifer	YAEC - Nuclear Eng. Dept.
Harold Eichenholz	NRC/Resident Inspector
Gregory A. Maret	YAEC - Reactor Engineering
Norman Lauben	NRC/RSB

ENCLOSURE 2

AGENDA

YANKEE PLANT AXIAL POWER SHAPE MEETING

10:00 INTRODUCTION — B. C. Slifer

10:15 CORE POWER DISTRIBUTIONS — R. J. Cacciapouti

- Yankee Core Characteristics
- Typical Axial Power Shapes
- Xe Transients: Durations and Axial Shapes
- Cycle 17 Measured vs. Predicted Power Distributions
- Impact of Rod Program on Cycle 17 Power Shapes
- Core Power Monitoring
- Application of Uncertainty Factors
- Basis for Cycle 18 Power Shapes

11:15 LOCA ANALYSIS — A. Husain

- Background Information
  - Basis for Previous Analyses
  - Axial Power Shape Discussions to Date
  - Response to NRC Letter of May 22, 1985
- Analysis for Cycle 17
- Analysis for Cycle 18
  - Prospective Methods Improvements
  - Axial Power Shapes

12:00 DISCUSSION

- Cycle 18 Schedules
- Basis for Cycle 18 Analysis

BCS
8/8/85

OBJECTIVES

1. To explain actions taken to assure compliance with 10CFR50.46 for Cycle 17.

2. To explain actions planned to assure compliance with 10CFR50.46 for Cycle 18.

3. To obtain NRC feedback on
   a) basis for axial power shapes for LOCA analysis
   b) statistical combination of uncertainties
   c) injection ΔP penalty reduction

4. To discuss Cycle 18 schedules.

5. Time permitting, to discuss future LOCA methods improvements.

BCS

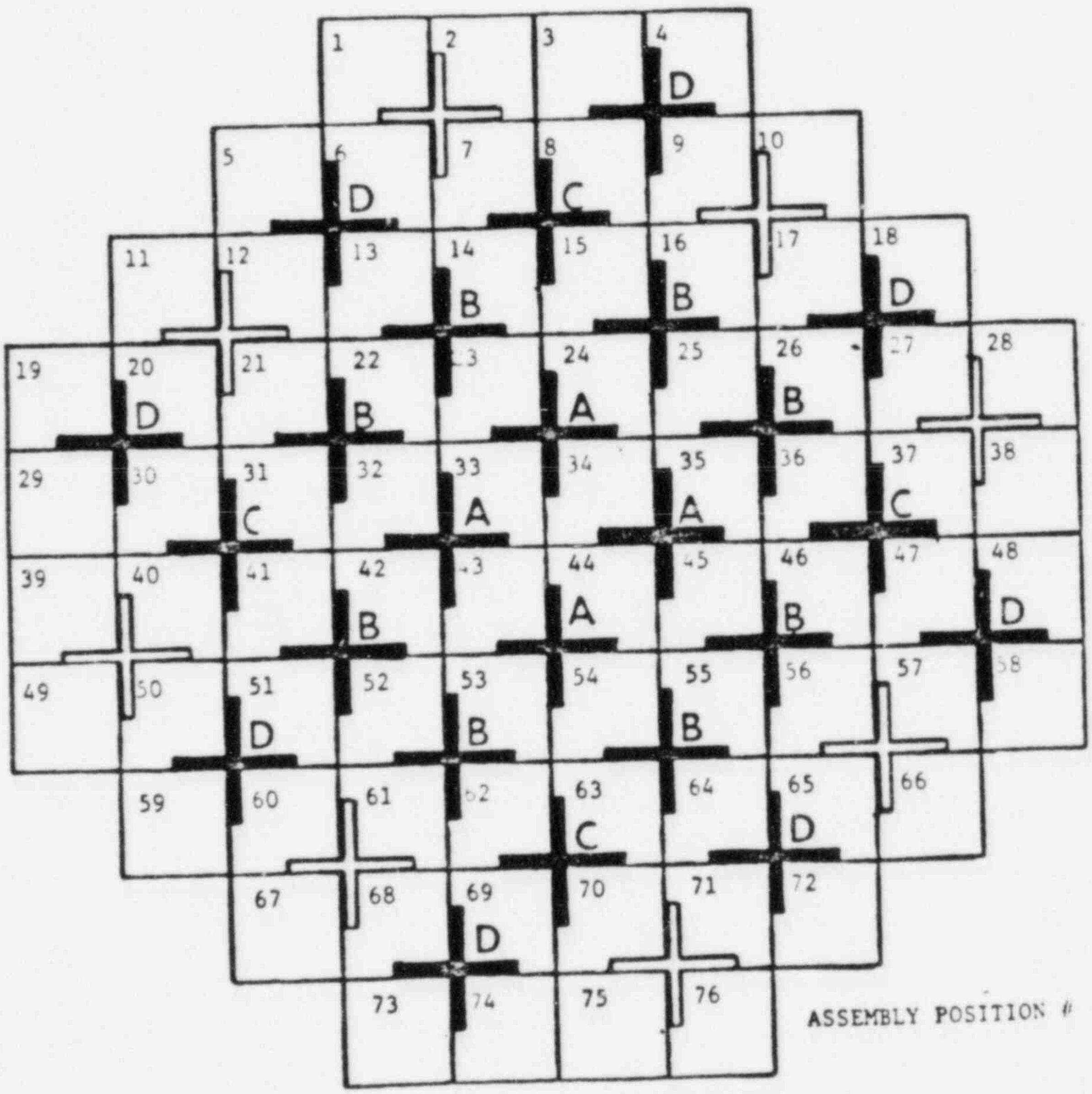
8/8/85

YANKEE ROWE CHARACTERISTICS

POWER LEVEL	600 MWT
NUMBER OF ASSEMBLIES	76
RODS PER ASSEMBLY	230/231
ACTIVE HEIGHT	7.5 ft.
CONTROL ROD	
TYPE	CRUCIFORM
NUMBER	24
GROUPS	4
MATERIAL	Ag-In-Cd

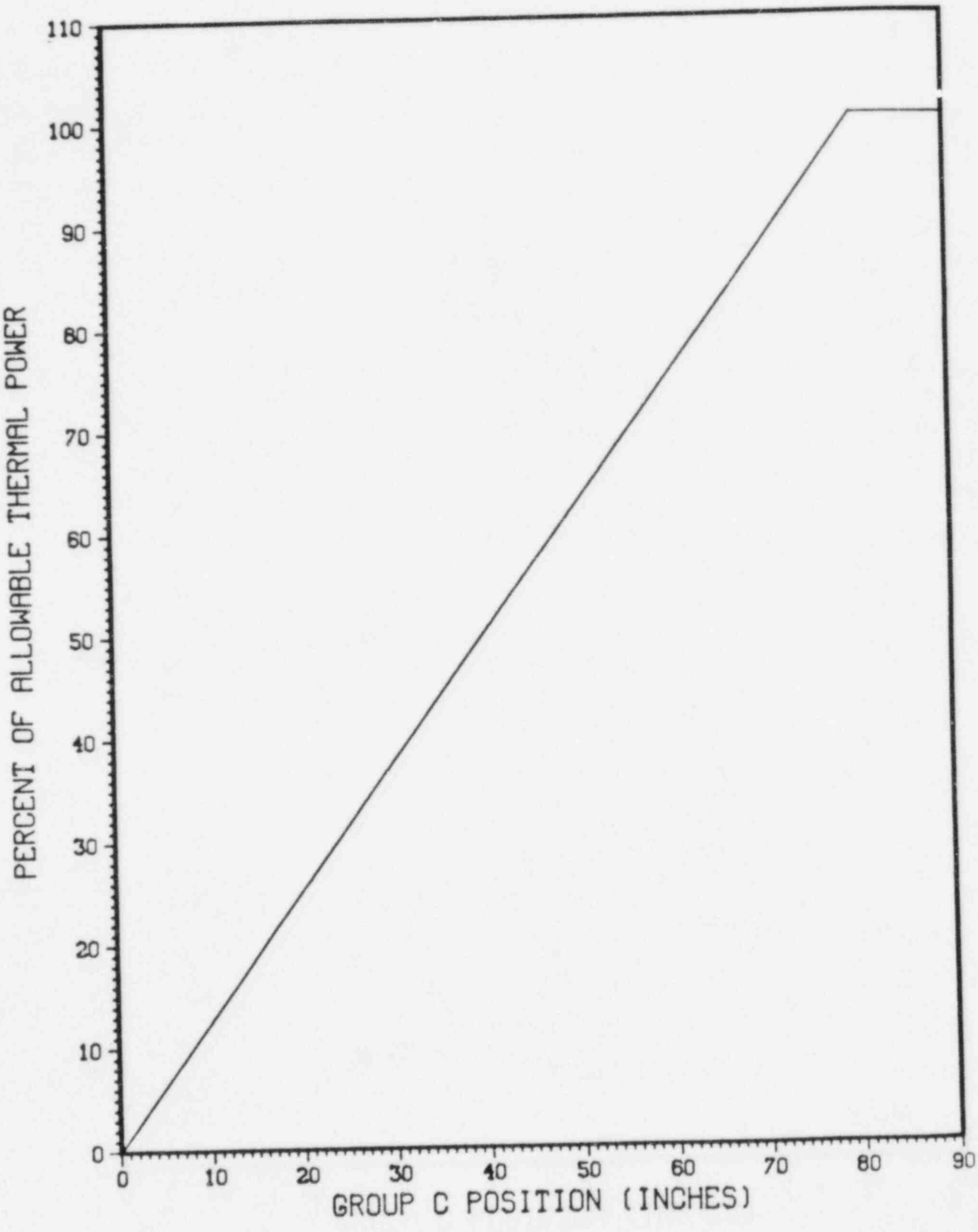
CONTROL ROD GROUP

IDENTIFICATION

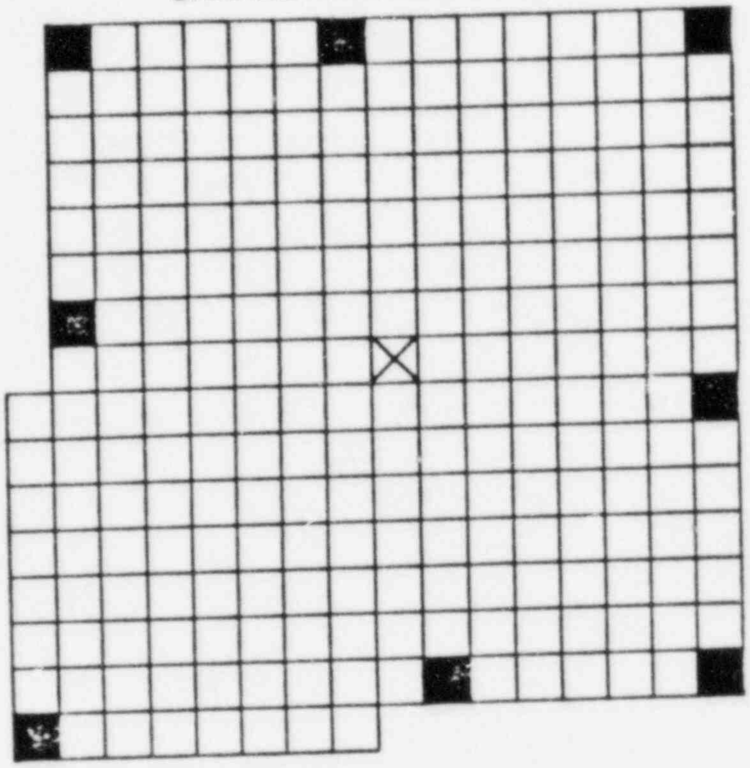


YANKEE CORE 17

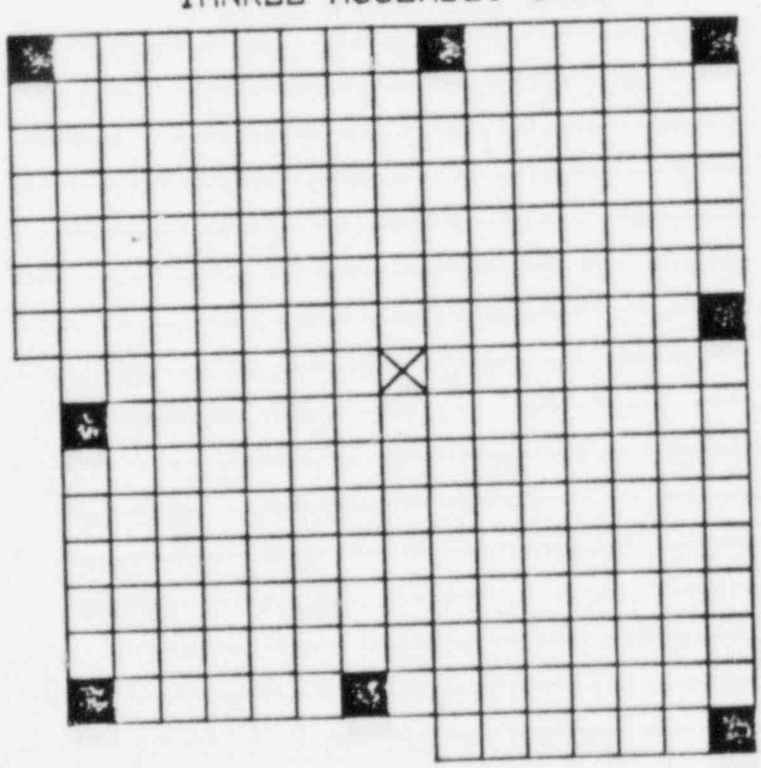
POWER DEPENDENT INSERTION LIMIT

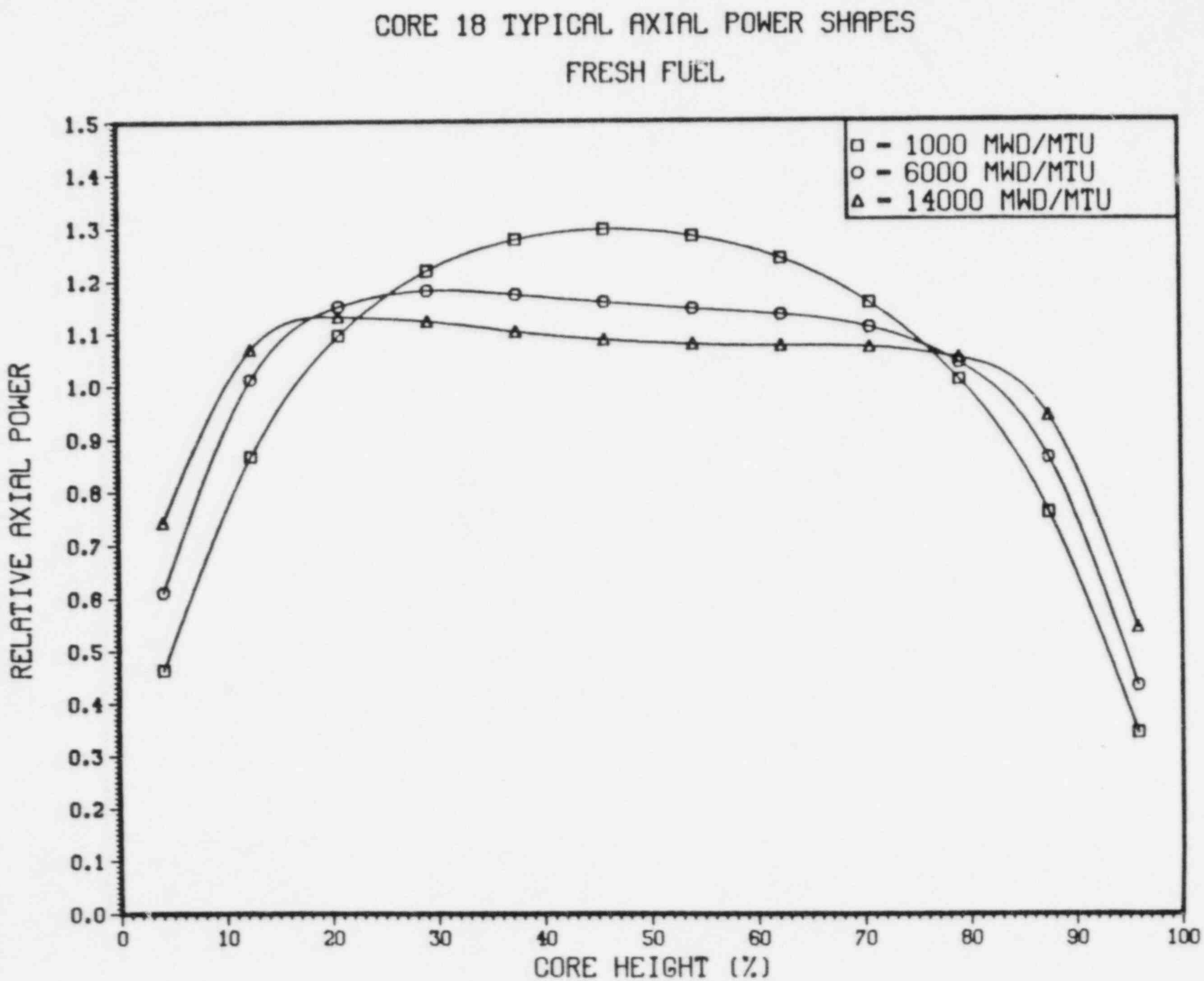


YANKEE ASSEMBLY TYPE A



YANKEE ASSEMBLY TYPE B



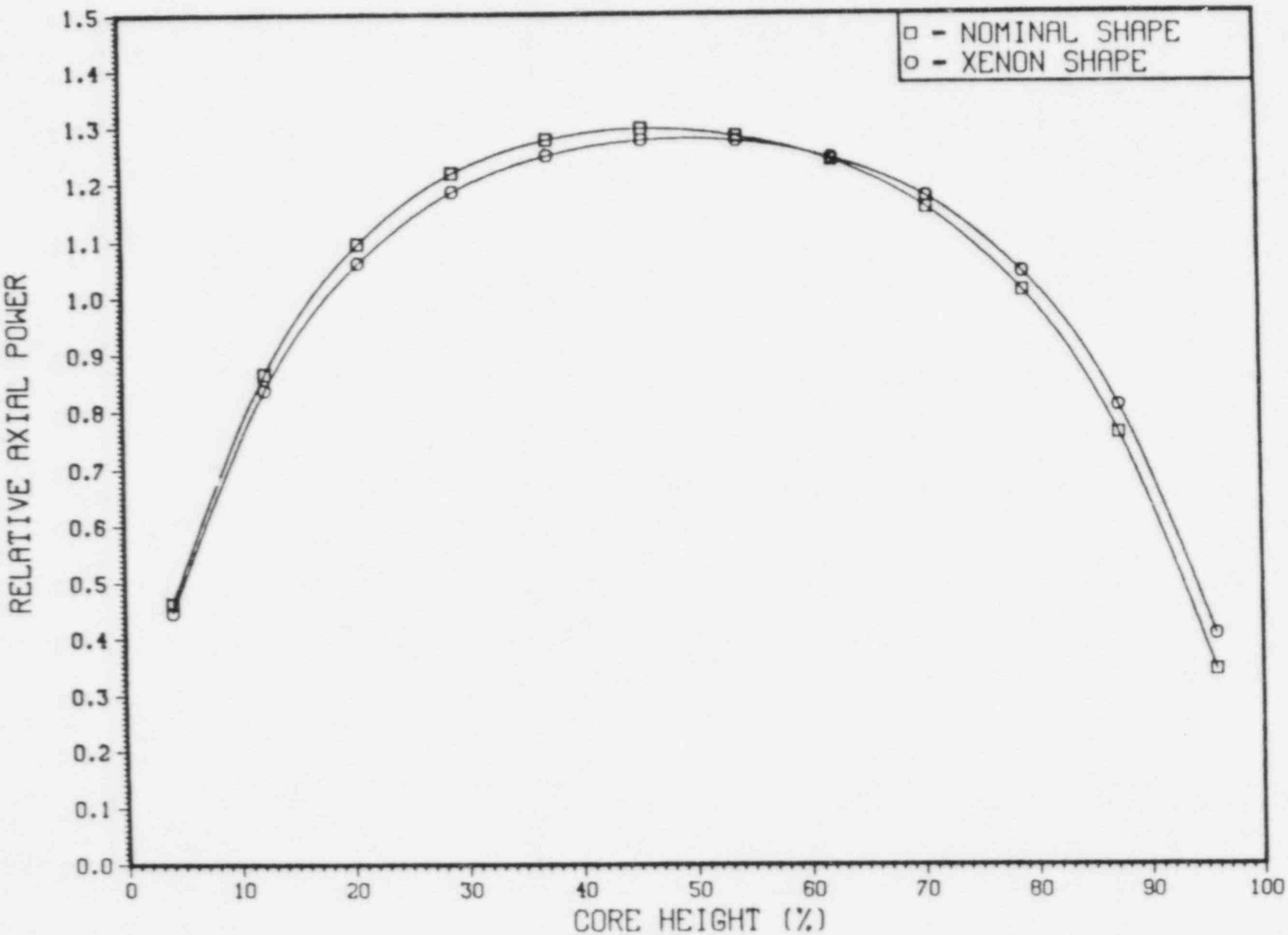


CORE 18 TYPICAL AXIAL POWER SHAPES
FRESH FUEL
□ - 1000 MWD/MTU
○ - 6000 MWD/MTU
△ - 14000 MWD/MTU
RELATIVE AXIAL POWER
CORE HEIGHT (%)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100

5

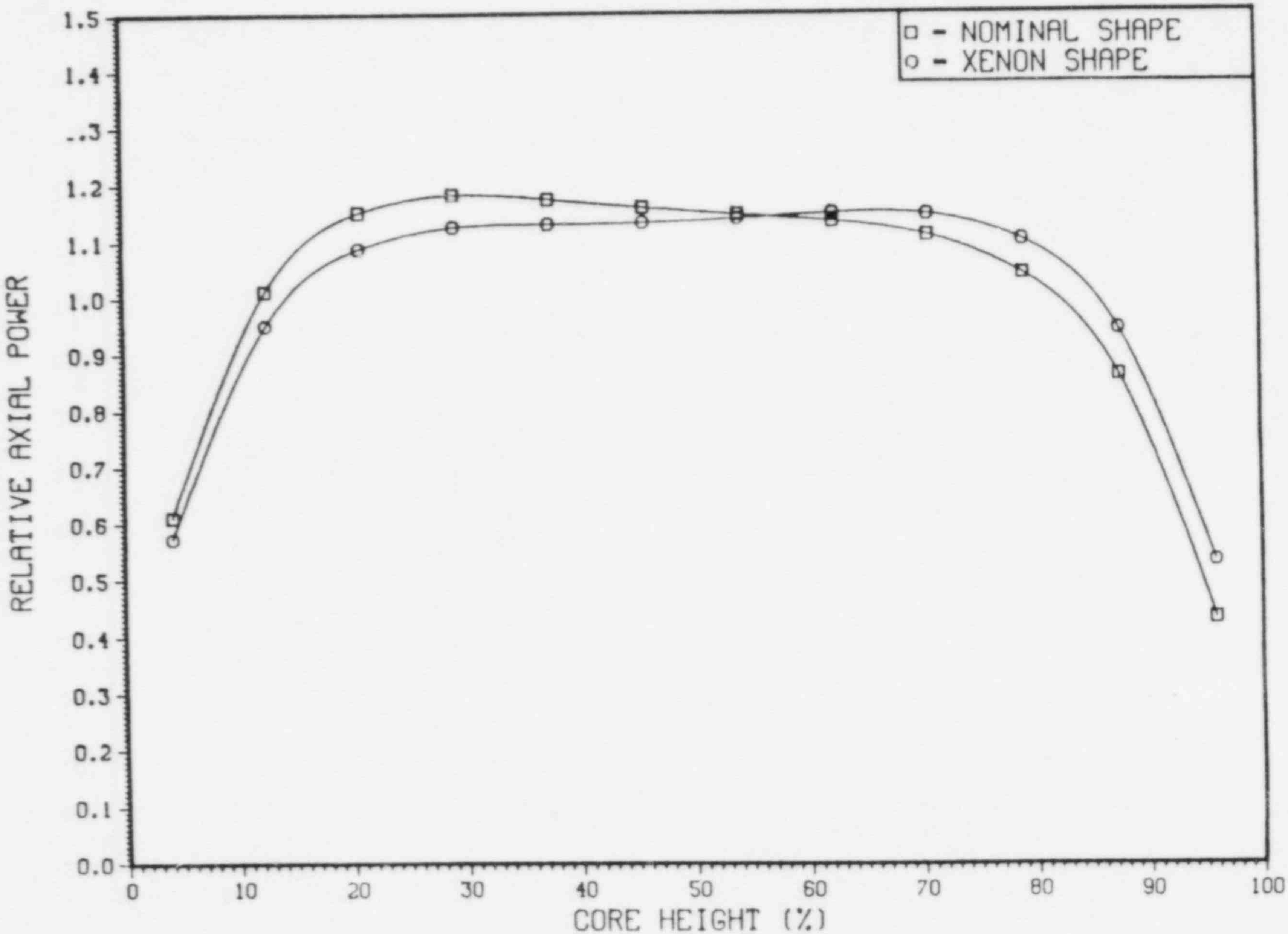
CORE 18 NOMINAL AND XENON POWER SHAPES

FRESH FUEL AT 1000 MWD/MTU



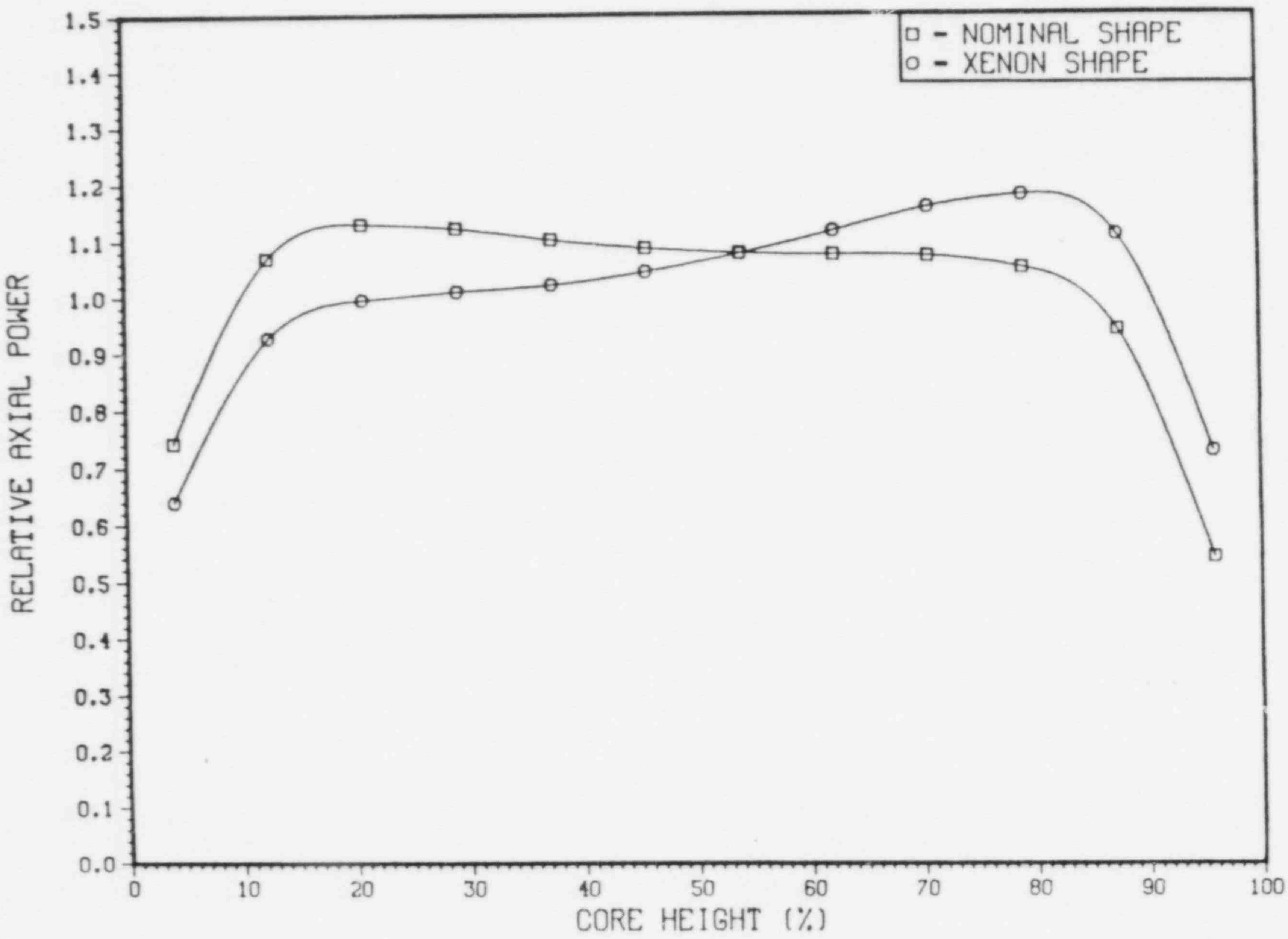
CORE 18 NOMINAL AND XENON POWER SHAPES

FRESH FUEL AT 6000 MWD/MTU



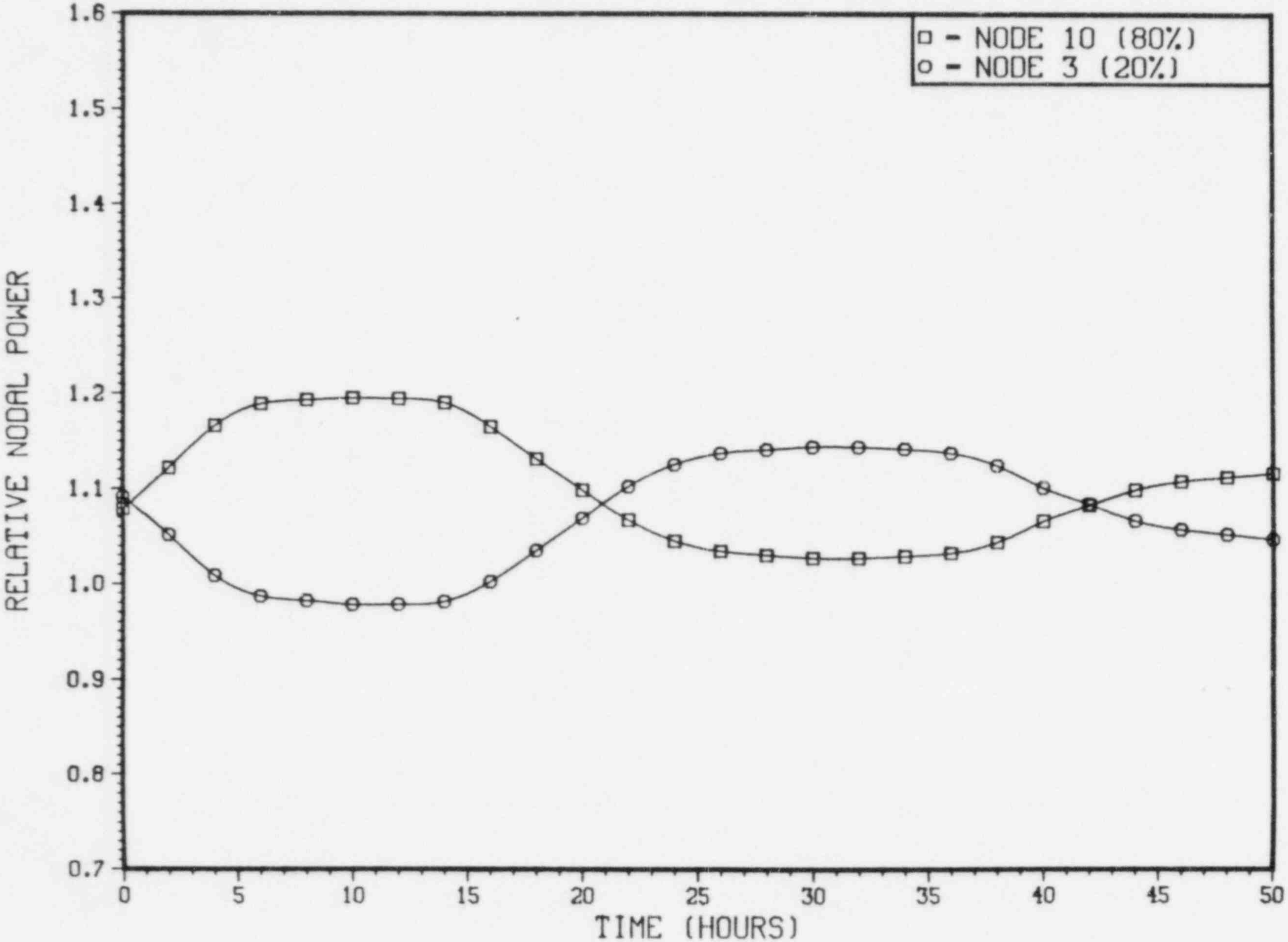
CORE 18 NOMINAL AND XENON POWER PROFILES

FRESH FUEL AT 14000 MWD/MTU



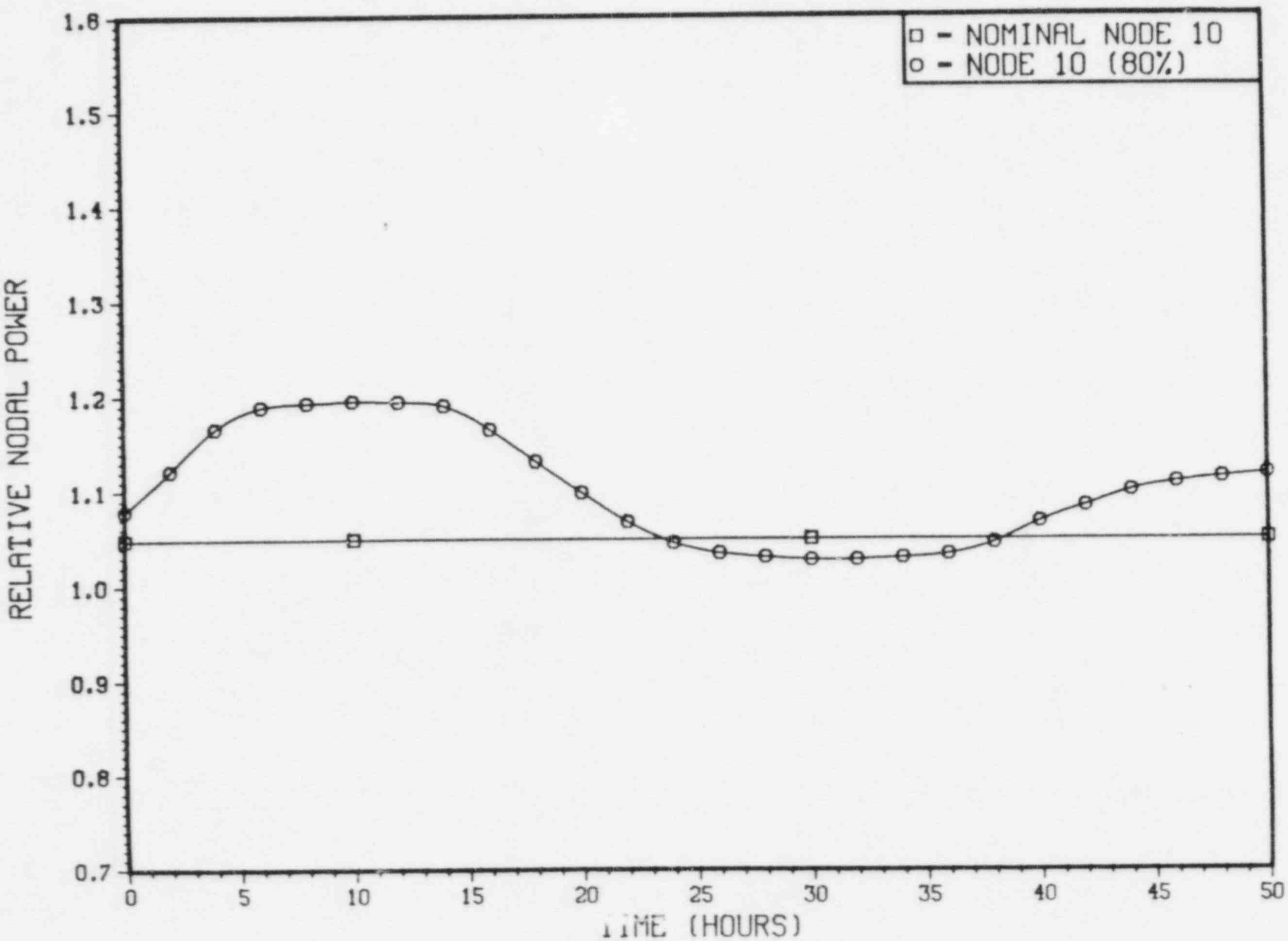
CORE 18 XENON TRANSIENT AT FULL POWER

CORE AVERAGE FOR NODES 10 AND 3



CORE 18 XENON TRANSIENT AT FULL POWER

CORE AVERAGE FOR NODE 10



COMPARISON OF MEASURED VS PREDICTED REACTION RATES
INCORE RUN YR-17-012
1337. MWD/MTU 599.7 MWT. GROUP C AT 83.8 INCHES

	A	B	C	D	E	F	G	H	J	K
1					.690 .687 .433					
2						.981 .987 -.588				
3				1.015 1.011 .395			1.003 .992 1.101			
4			1.011 1.009 .220		1.107 1.097 .895					
5				1.146 1.144 .255				1.093 1.093 .047		
6							1.142 1.136 .518			
7						1.115 1.115 .032		1.019 1.004 1.573		
8							1.018 1.023 -.463			
9			.864 .890 -3.097		.994 1.013 -1.902					
10										

MEASURED
PREDICTED

% DIFF

COMPARISON OF MEASURED VS PREDICTED REACTION RATES
INCORE RUN YR-17-018
6873. MWD/MTU 599.9 MWT. GROUP C AT 82.875 INCHES

	A	B	C	D	E	F	G	H	J	K
1					.891 .897 -.917					
2						.983 1.000 -1.695				
3				1.028 1.020 .790			1.018 1.011 .686			
4			1.024 1.014 1.016		1.104 1.094 .892					
5				1.125 1.125 .008				1.092 1.093 -.067		
6							1.124 1.123 .086			
7						1.102 1.102 .023		1.028 1.012 1.572		
8							1.026 1.024 .238			
9			.863 .880 -2.554		.992 1.005 -1.320					
10										

MEASURED
PREDICTED
% DIFF

COMPARISON OF MEASURED VS PREDICTED REACTION RATES
INCORE RUN YR-17-023
11840.0 MWD/MTU 599.0 MWT. GROUP C AT 82.125 INCH

	A	B	C	D	E	F	G	H	J	K
1					.693 .701 -1.157					
2						.990 1.009 -1.885				
3				1.036 1.031 .584			1.036 1.028 .743			
4			1.034 1.024 1.006		1.101 1.091 .884					
5				1.110 1.107 .282				1.080 1.088 -.707		
6							1.108 1.107 .088			
7						1.094 1.094 .046		1.037 1.024 1.283		
8							1.033 1.030 .304			
9			.654 .662 -1.189		.992 1.004 -1.134					
10										

MEASURED
PREDICTED
% DIFF

COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-013
599.9 MWT. GROUP C AT 85.0 INCHES 1172. MWD/MTU

				0.605 0.614 -1.455					
					1.064 1.079 -1.450				
			1.016 1.029 -1.241			1.034 1.051 -1.663			
		1.031 1.051 -1.901		1.100 1.085 1.385					
			1.084 1.063 1.987				1.019 1.024 -0.492		
						1.074 1.063 1.041			
					1.110 1.085 2.311		1.045 1.051 -0.573		
			1.045 1.051 -0.569			1.028 1.029 -0.058			
		0.662 0.646 2.446		1.084 1.079 0.404					

MEASURED SIGNAL
PREDICTED SIGNAL
PERCENT DIFFERENCE

COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-025
599.9 MWT. GROUP C AT 84.6 INCHES 6492. MWD/MTU

				0.645 0.645 0.039					
					1.030 1.042 -1.188				
			1.038 1.037 0.148			1.042 1.047 -0.476			
		1.040 1.047 -0.691		1.090 1.089 0.092					
			1.077 1.073 0.391				1.040 1.040 0.020		
						1.075 1.073 0.196			
					1.090 1.089 0.133		1.051 1.047 0.393		
			1.042 1.047 -0.487			1.033 1.037 -0.293			
		0.868 0.845 3.046		1.040 1.042 -0.171					

MEASURED SIGNAL
PREDICTED SIGNAL
PERCENT DIFFERENCE

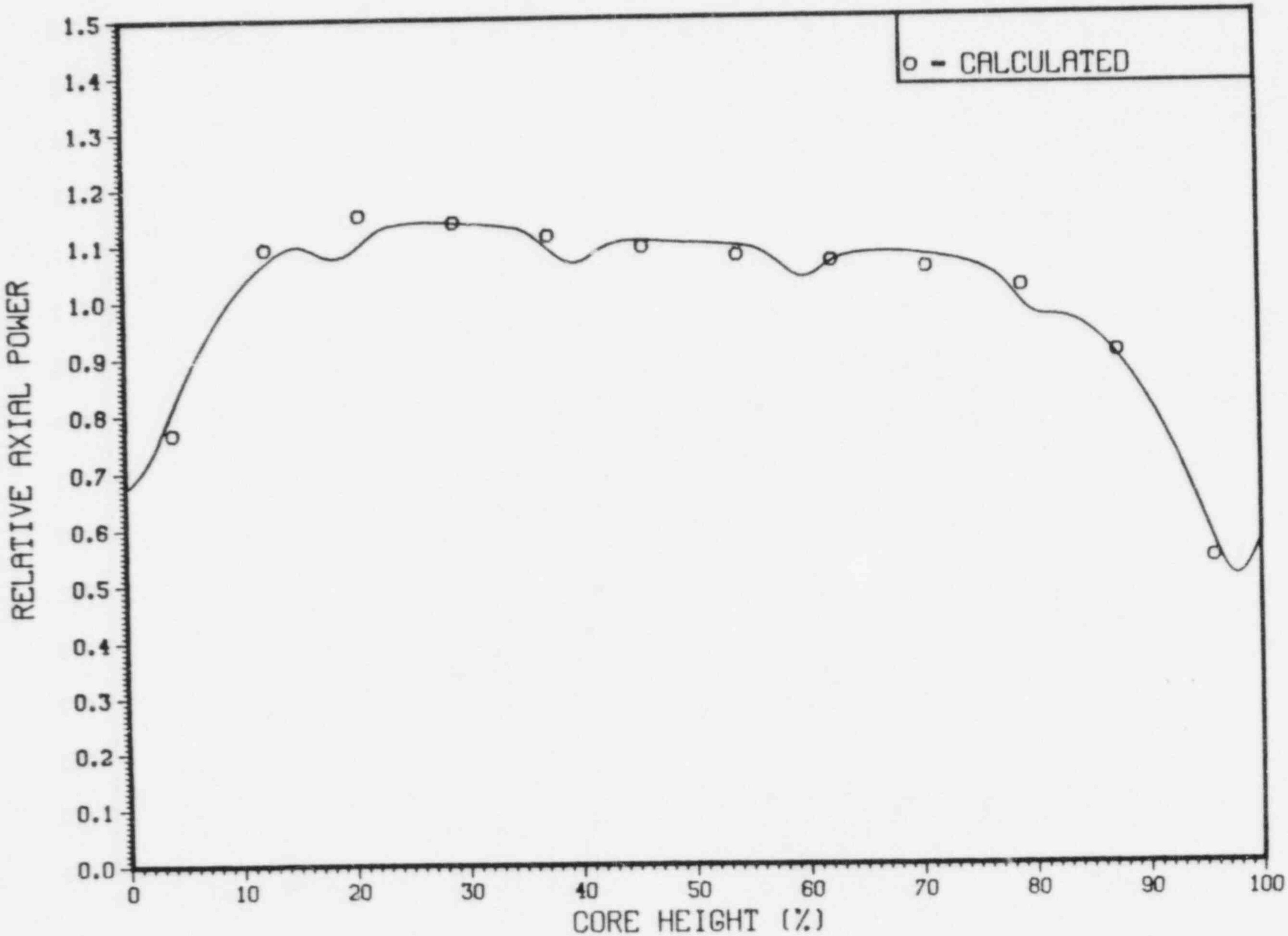
COMPARISON OF MEASURED AND PREDICTED SIGNALS
INCORE RUN YR-16-035
599.8 MWT. GROUP C AT 85.6 INCHES 12420. MWD/MTU

				0.689 0.666 3.505					
					1.023 1.022 0.132				
			1.045 1.042 0.294			1.046 1.047 -0.097			
		1.045 1.047 -0.141		1.088 1.086 0.214					
			1.078 1.075 0.317				1.044 1.049 -0.494		
						1.072 1.075 -0.287			
					1.075 1.086 -0.991		1.045 1.047 -0.177		
			1.045 1.047 -0.165			1.029 1.042 -1.241			
		0.662 0.648 2.110		1.013 1.022 -0.892					

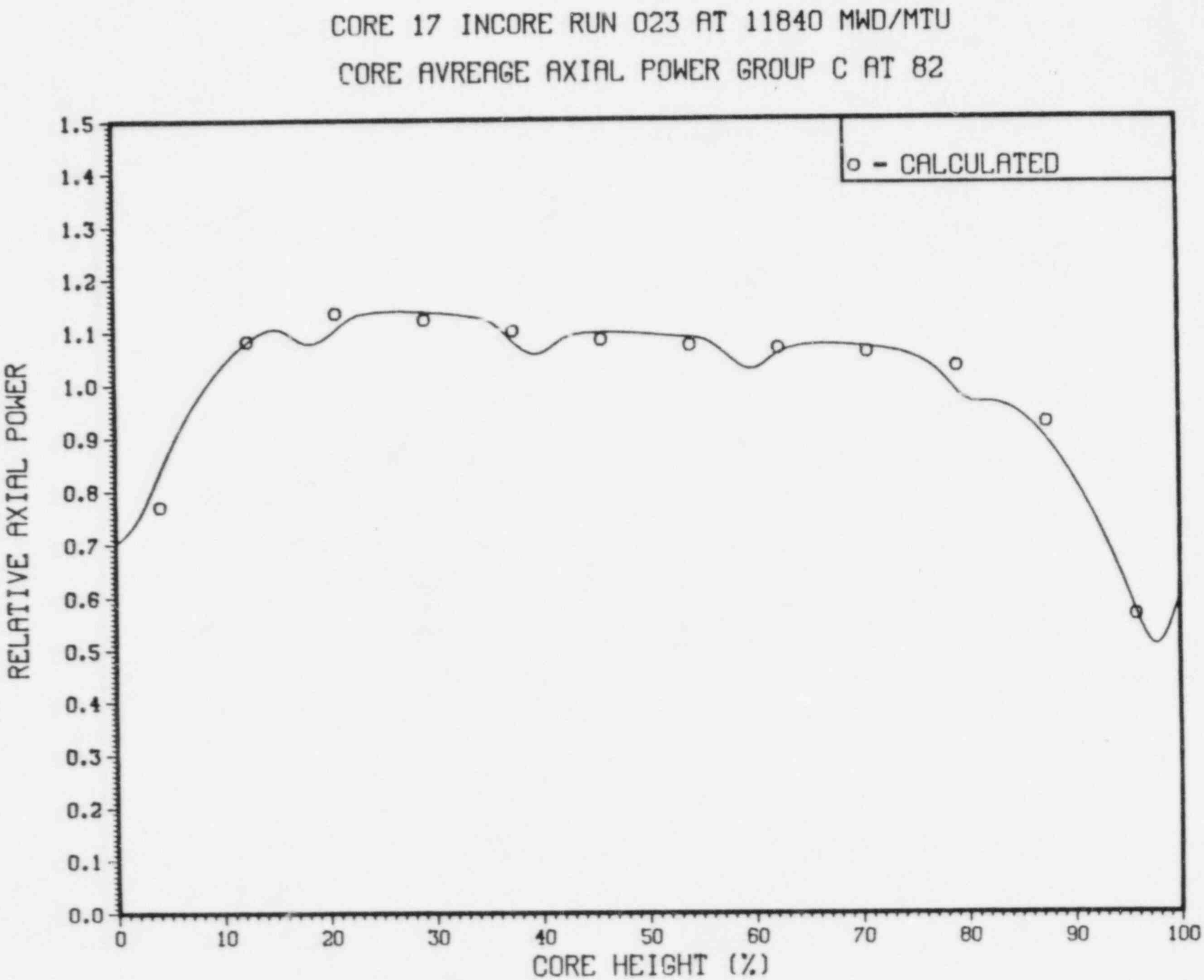
MEASURED SIGNAL
PREDICTED SIGNAL
PERCENT DIFFERENCE

CORE 17 INCORE RUN 022 AT 10677 MWD/MTU

CORE AVREAGE AXIAL POWER GROUP C AT 82

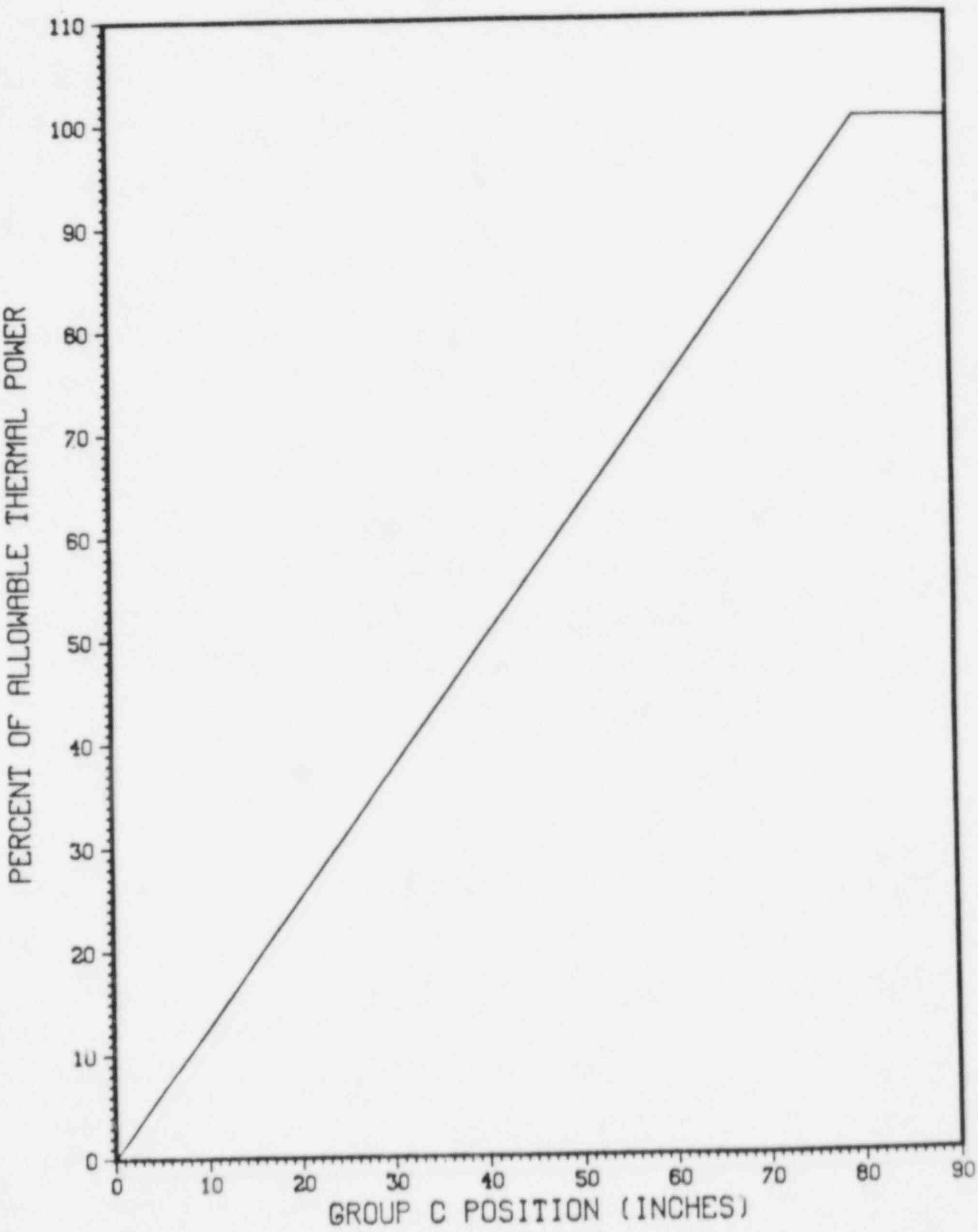


17


CORE 17 INCORE RUN 023 AT 11840 MWD/MTU
CORE AVREAGE AXIAL POWER GROUP C AT 82
o - CALCULATED
RELATIVE AXIAL POWER
CORE HEIGHT (%)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
0
10
20
30
40
50
60
70
80
90
100

YANKEE CORE 17

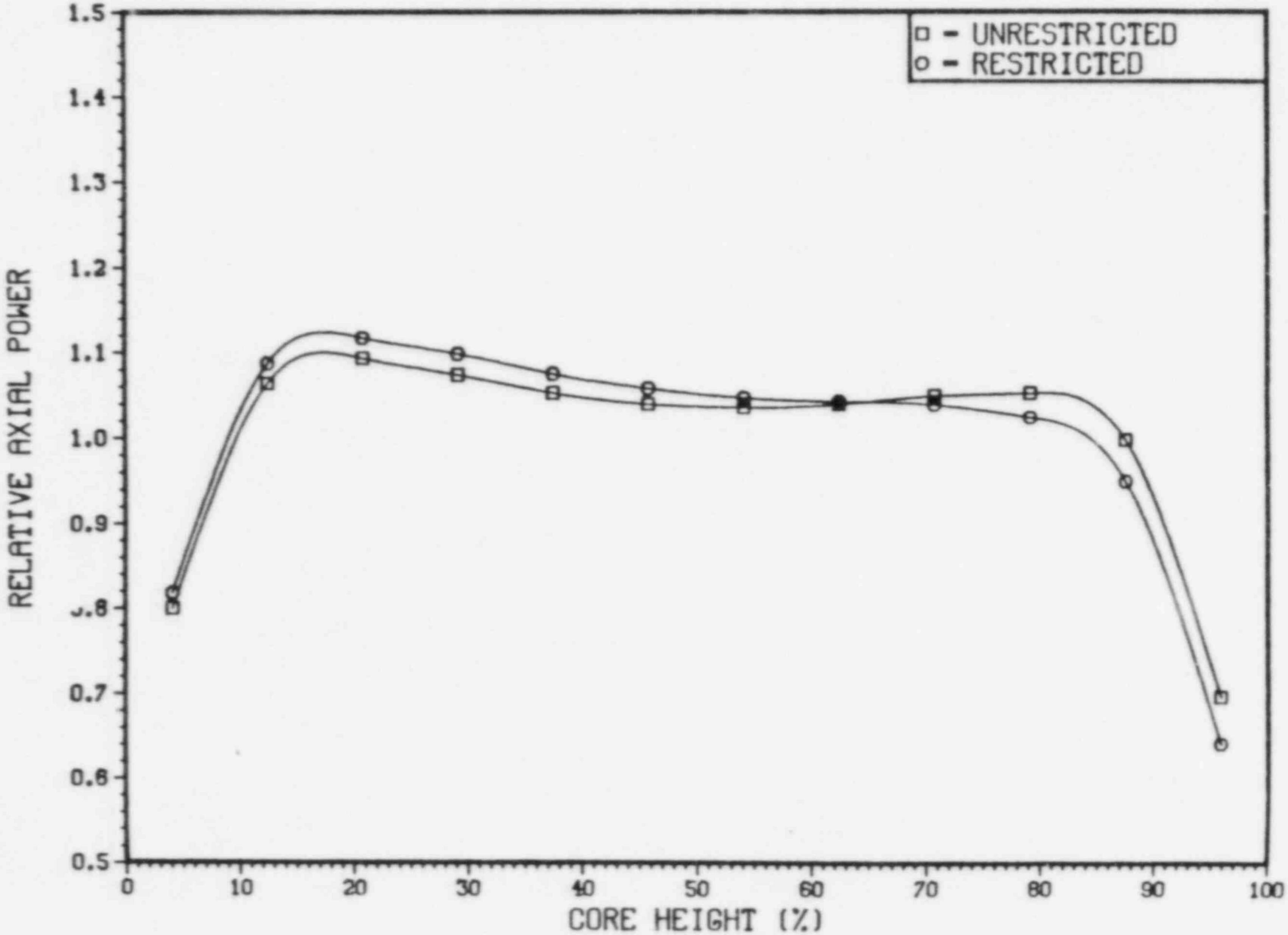
POWER DEPENDENT INSERTION LIMIT



CORE 17 COMPARISON OF AXIAL PROFILES

RESTRICTED AND UNRESTRICTED ROD MOTION

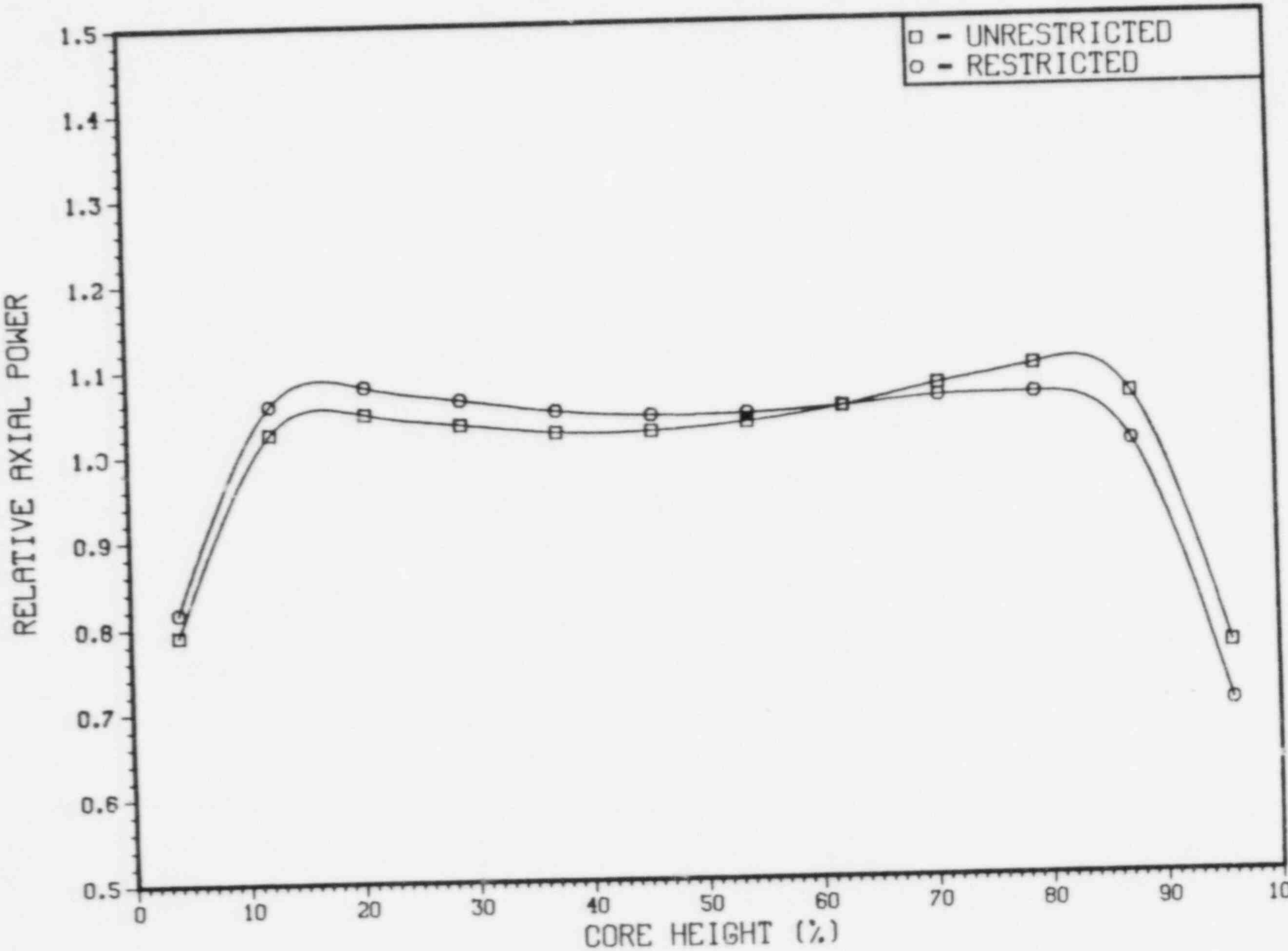
BURNED FUEL AT 10000 MWD/MTU



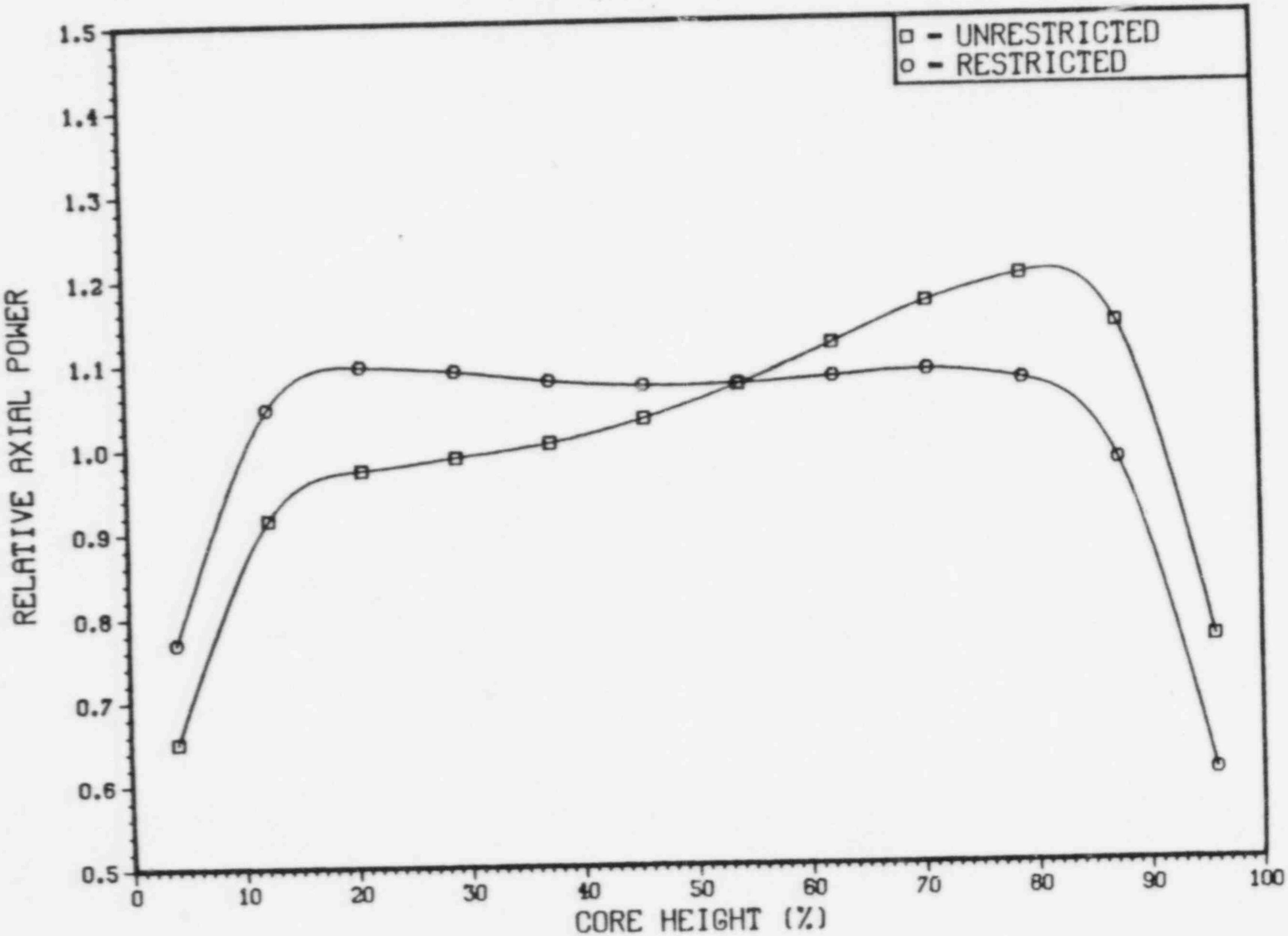
CORE 17 COMPARISON OF AXIAL PROFILES

RESTRICTED AND UNRESTRICTED ROD MOTION

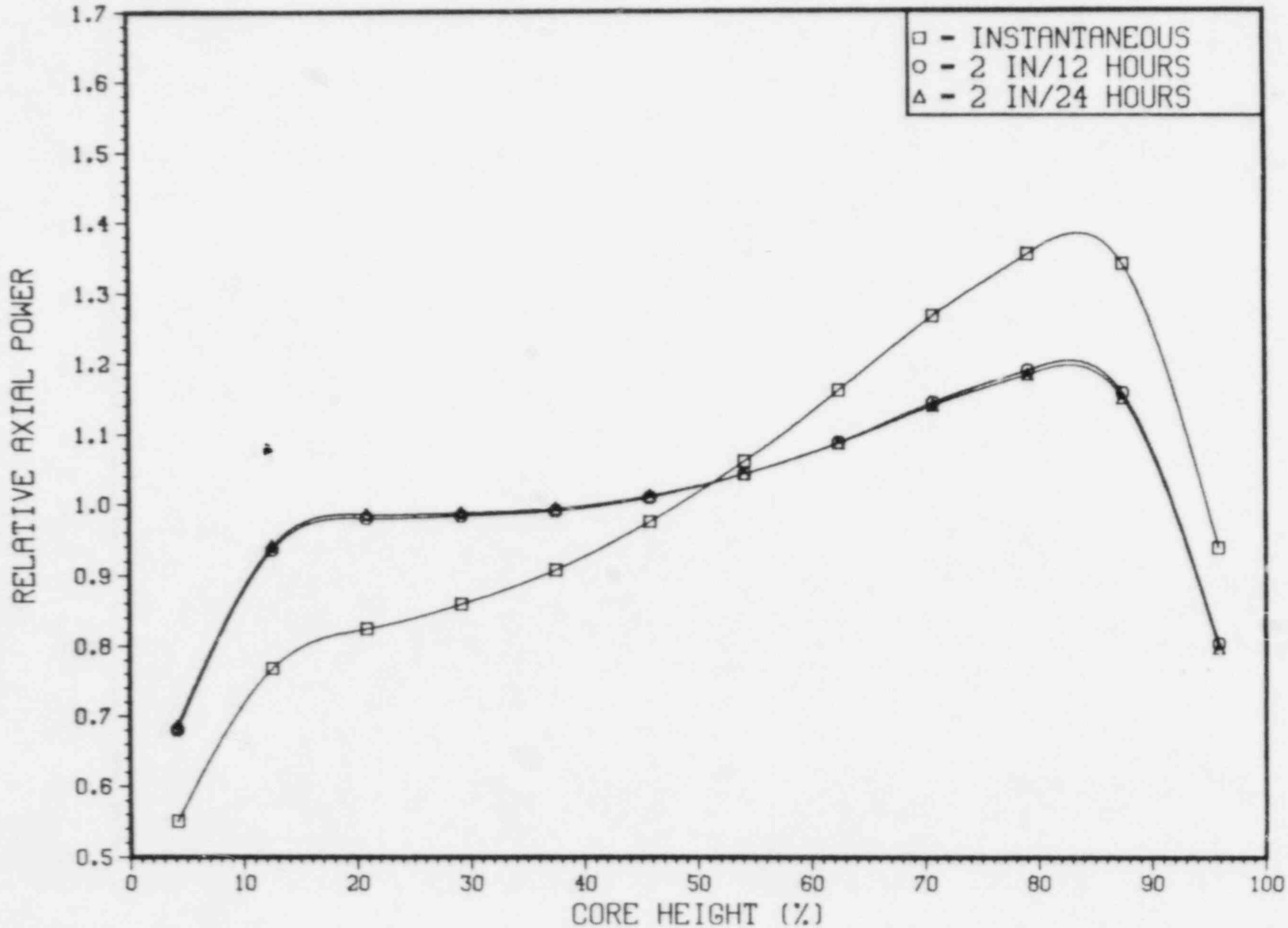
BURNED FUEL AT 12500 MWD/MTU



CORE 17 COMPARISON OF XENON AXIAL PROFILES
RESTRICTED AND UNRESTRICTED ROD MOTION
CORE AVERAGE AXIAL AT 12500 MWD/MTU



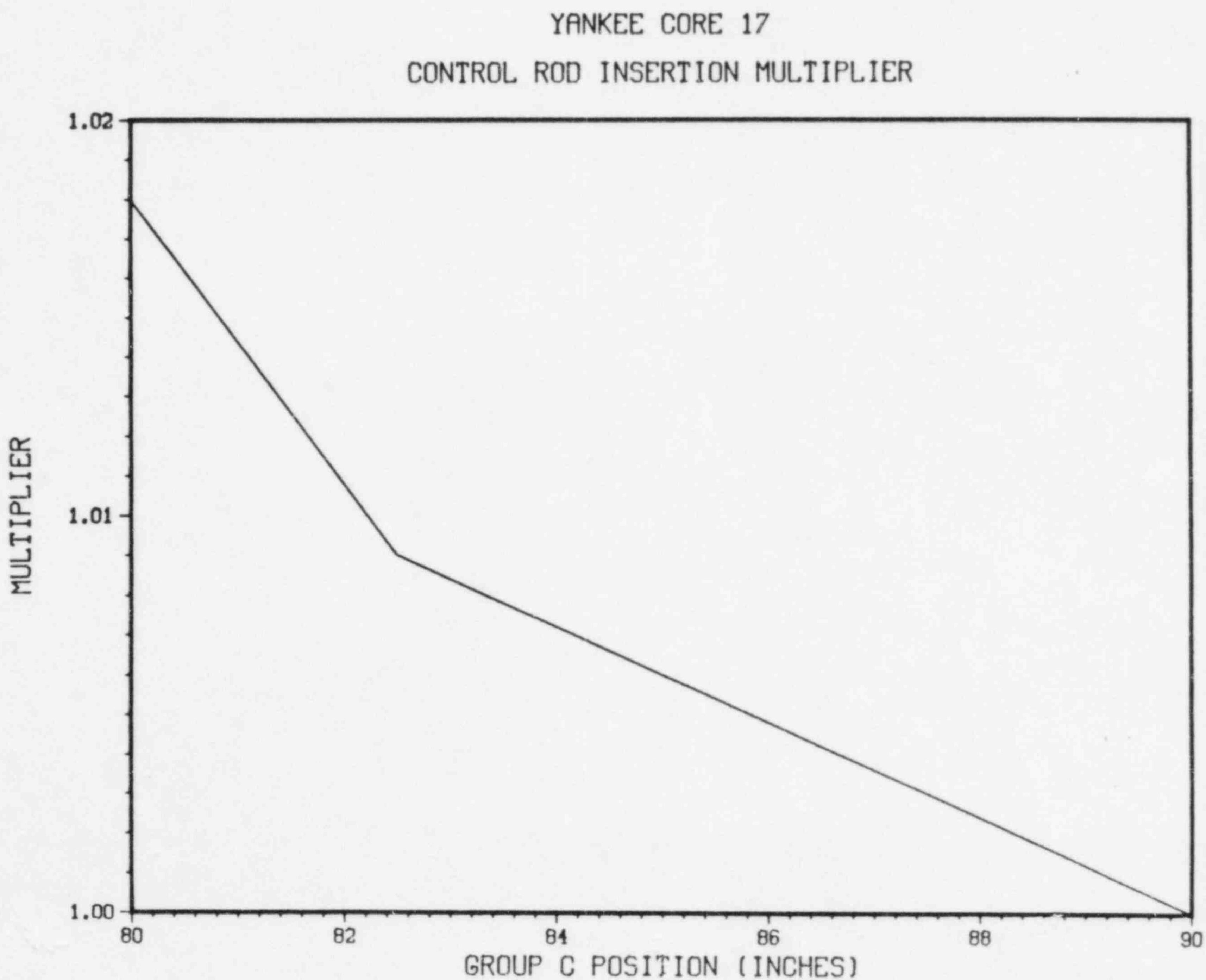
CORE 17 COMPARISON OF AXIAL PROFILES
RESTRICTED AND UNRESTRICTED ROD MOTION
CORE AVERAGE AXIAL AT 85 % POWER IN COASTDOWN



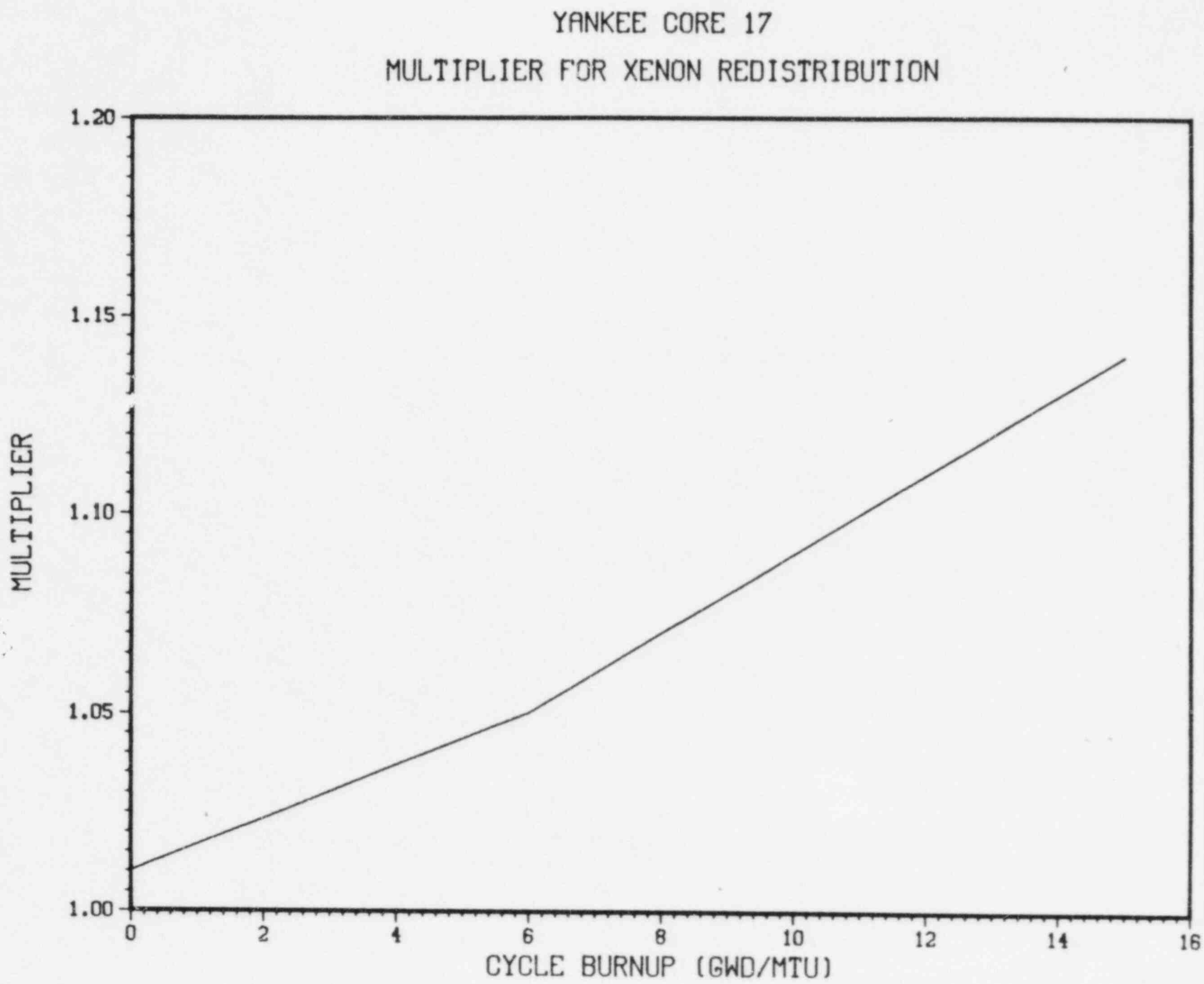
POWER DISTRIBUTION LIMITS TECHNICAL SPECIFICATION

$$\ell_{MAX} = F_{XY} F_Z F_U F_{SS} F_P F_E F_I F_{XE} \bar{\ell}$$

F_{XY}	RADIAL POWER
F_Z	AXIAL PEAK -TO- AVERAGE
F_U	MEASUREMENT UNCERTAINTY (1.068)
F_{SS}	STACK SHORTENING (1.009)
F_P	POWER UNCERTAINTY (1.03)
F_E	ENGINEERING FACTOR (1.04)
F_I	ROD INSERTION FACTOR
F_{XE}	XENON REDISTRIBUTION FACTOR
$\bar{\ell}$	AVERAGE KW/FT


YANKEE CORE 17
CONTROL ROD INSERTION MULTIPLIER
1.02
1.01
1.00
MULTIPLIER
80
82
84
86
88
90
GROUP C POSITION (INCHES)

25


YANKEE CORE 17
MULTIPLIER FOR XENON REDISTRIBUTION
1.20
1.15
1.10
1.05
1.00
MULTIPLIER
0
2
4
6
8
10
12
14
16
CYCLE BURNUP (GWD/MTU)

STATISTICAL COMBINATION

F_U MEASUREMENT UNCERTAINTY (1.068)

F_P POWER UNCERTAINTY (1.03)

F_E ENGINEERING FACTOR (1.04)

MULTIPLICITIVE (1.144)

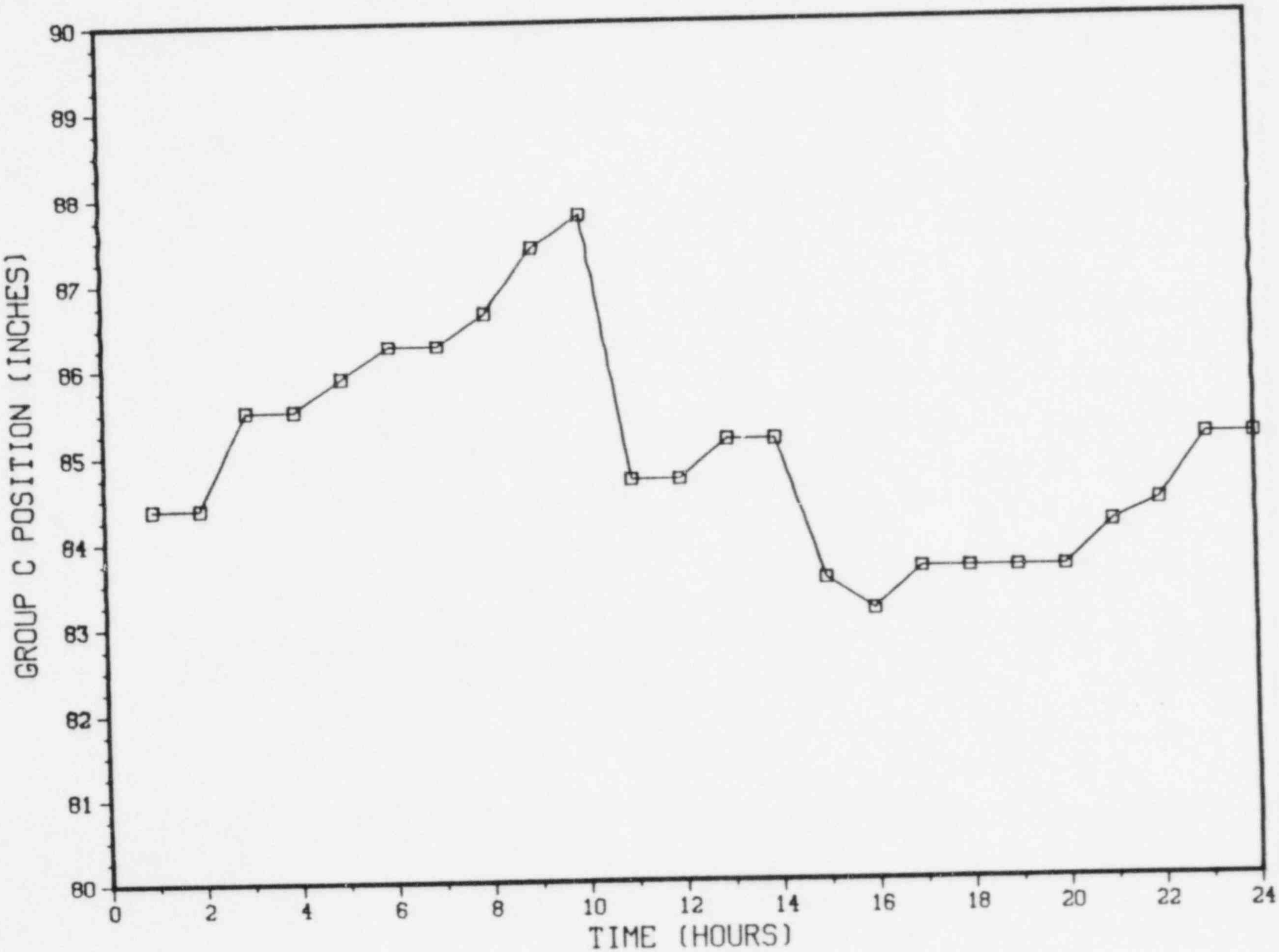
STATISTICAL (1.084)

CORE 18
BASIS FOR POWER SHAPE

NOMINAL

XENON INDUCED

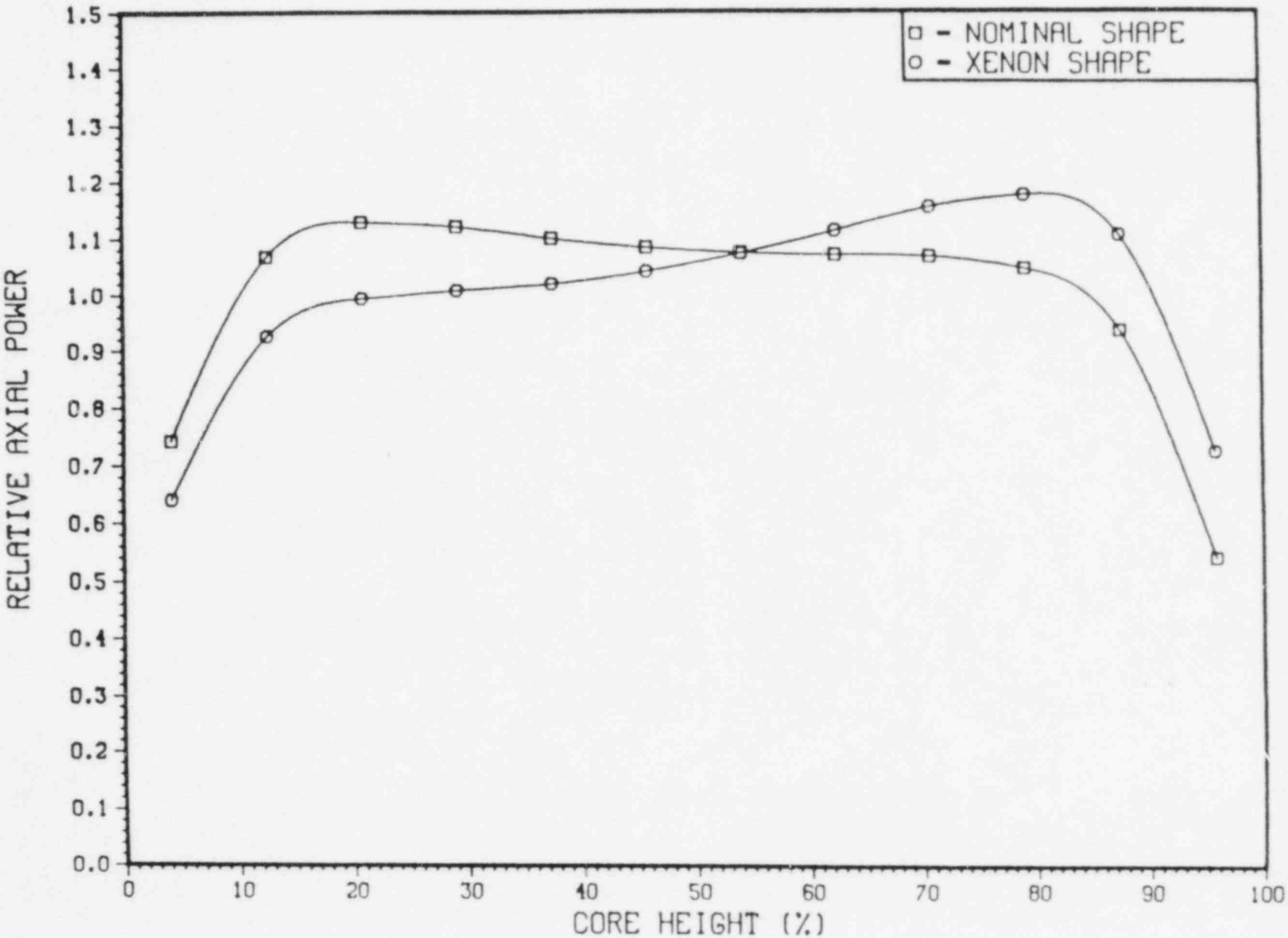
CORE 17 TYPICAL ROD MANEUVERS
STEADY STATE FULL POWER OPERATION



29

CORE 18 NOMINAL AND XENON POWER PROFILES

FRESH FUEL AT 14000 MWD/MTU



YANKEE LOCA METHODOLOGY

ORIGINAL

- O XN-75-41 VOLUMES I TO III AND SUPPLEMENTS 1 TO 7
- O GENERIC SER ON H B ROBINSON SEPTEMBER 11, 1975
- O YR SAMPLE PROBLEM XN-75-41 APPENDIX C
  CHOPPED COSINE POWER SHAPE USED
- O YR SER DECEMBER 4, 1975
  - APPLICABILITY OF GENERIC METHOD
  - SPECIAL REVIEW OF SHORTER CORE, THINNER FUEL ROD, DIFFERENT ACCUMULATOR CONFIGURATION
  - GENERIC MODEL CONSERVATIVELY COVERED

MODEL CHANGES AT YAEC

- O REVISED CALCULATION OF EOBY 3/77
- O LOW FLOW FILM BOILING HTC 6/77
- O CORE FLOOD RATE STABILIZATION 7/77
- O LOWER PLENUM PHASE SEPARATION MODEL 11/80
- O RELAP5YA METHOD DEVELOPMENT (IN PROGRESS)

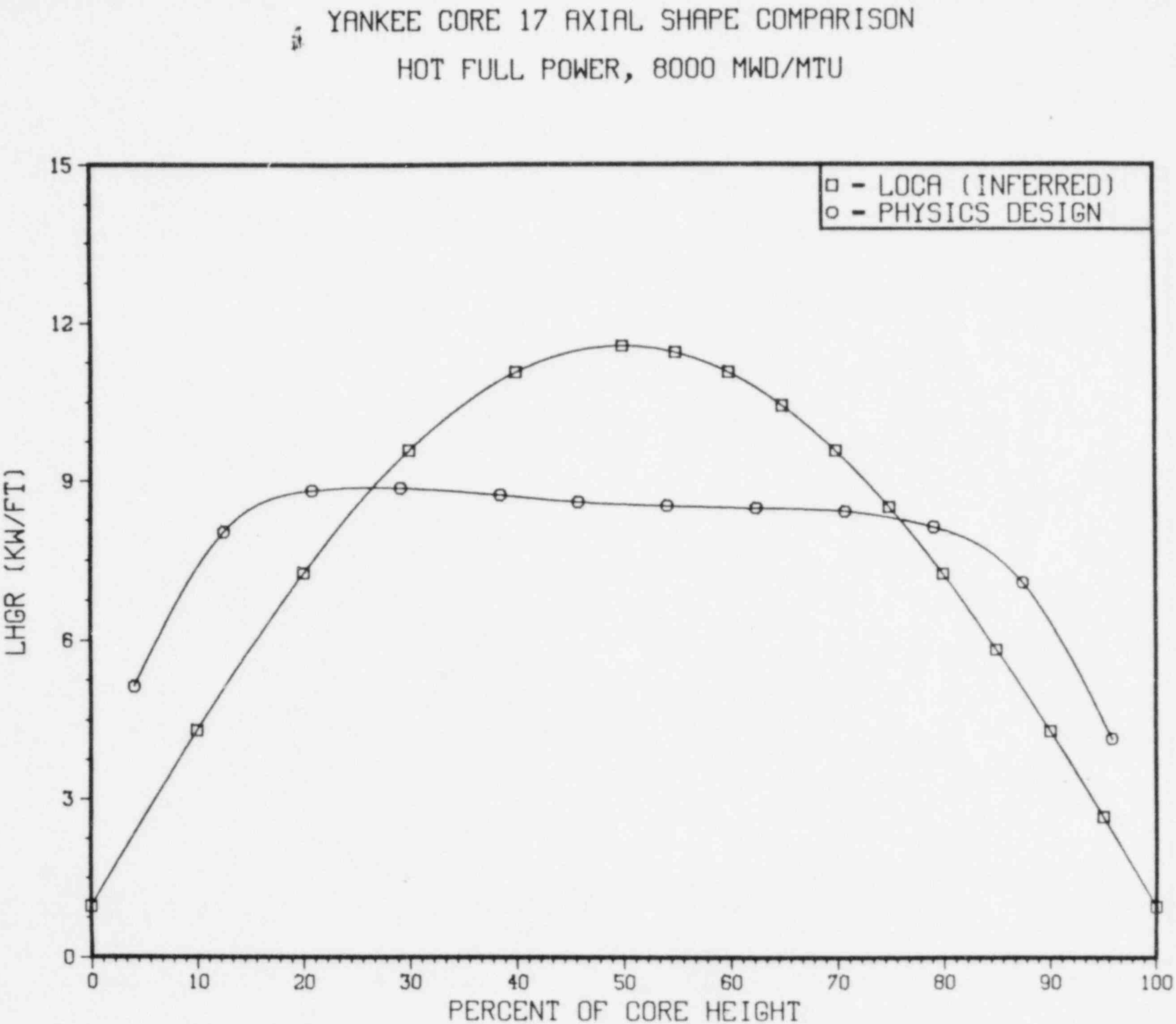
Axial Power Shape Discussions

0 March 29, 1985 (Call from NRC)

- EXXON Concerns Applicable to Yankee Plant
- YP Uses Cosine Power Shape
- Yankee Will Assess Power Shape Impact

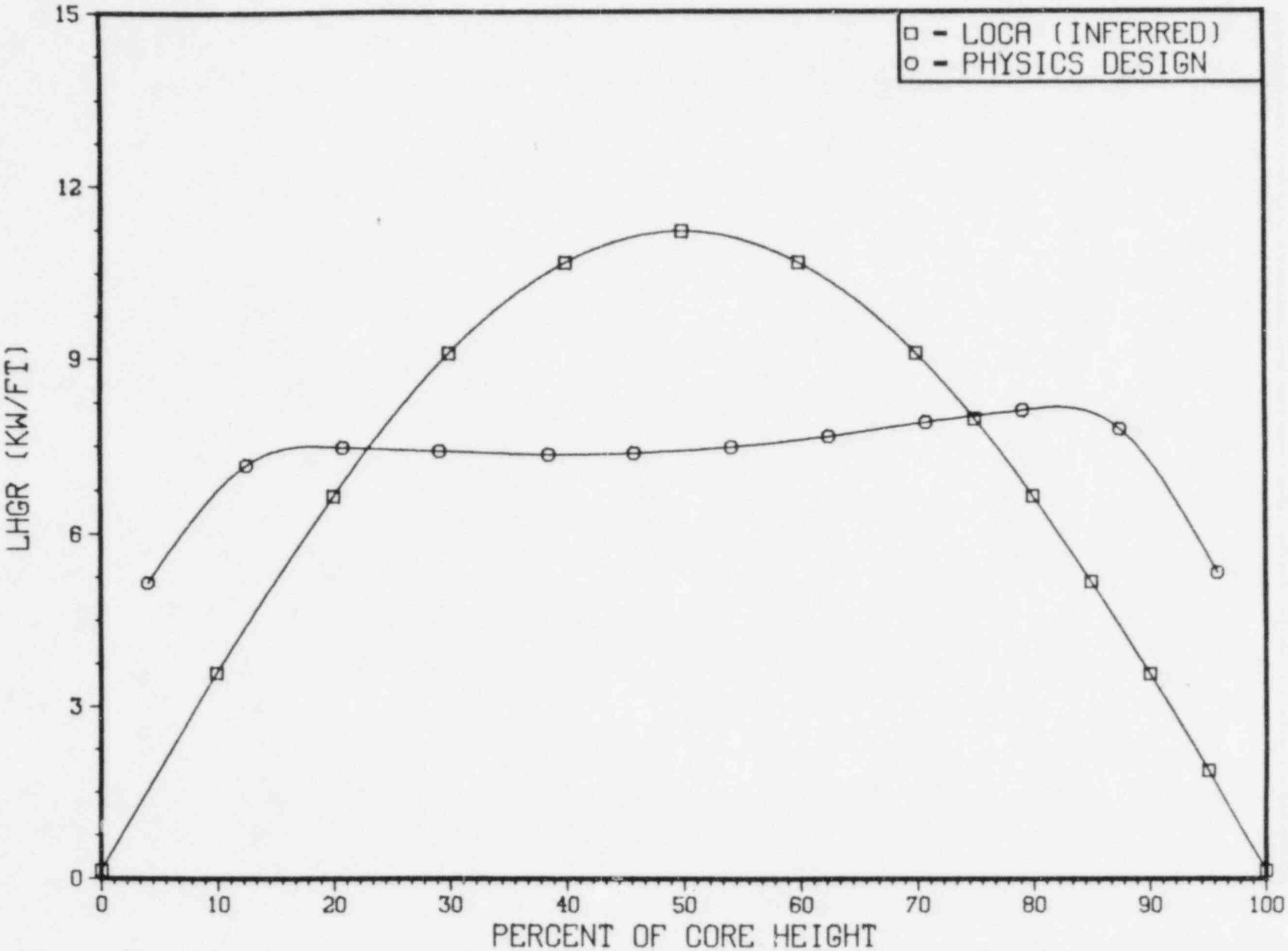
0 April ~~15~~ 9, 1985 (Call from Yankee)

- Actual Power Shape Flat at EOC
- Actual Peak 8.2 KW/ft; Analyzed Peak 11.2 KW/ft
- At 80% Elevation; Actual KW/ft > Analyzed KW/ft
- Existing Cosine TOODEE-2 Run Reanalyzed With Actual Power Shapes at Higher Elevations.
- PCT < 2200°F
- NRC to call back for more information, if needed.


YANKEE CORE 17 AXIAL SHAPE COMPARISON
HOT FULL POWER, 8000 MWD/MTU
□ - LOCA (INFERRED)
○ - PHYSICS DESIGN
LHGR (KW/FT)
PERCENT OF CORE HEIGHT
0
3
6
9
12
15
0
10
20
30
40
50
60
70
80
90
100

YANKEE CORE 17 AXIAL SHAPE COMPARISON

HOT FULL POWER, 12500 MWD/MTU



4

Cycle 17 Reanalysis Activities

Full Power Operation

0 Xe Induced Top Skew Power Shapes May Lead to Derate

0 Existing Licensing Analyses Will Cover Bottom Skewed Power Shapes

0 Rodded Operation Will Force Bottom Skewed Power Shapes

0 Plant Was Ordered to Insert Rods (80" to 83")

0 Bottom Peak With Tech.Spec. Limit of 11.2 KW/ft Was Analyzed

0 PCT $< 2200^{0}$F

POWER COAST DOWN ANALYSIS

0 ROD WITHDRAWAL BEYOND 83" REQUIRED

0 PCT < $2200^{\circ}F$, IF

- POWER ≤ 85%
- ROD WITHDRAWAL RATE ≤ 2" PER DAY

INJECTION ΔP PENALTY

0 CURRENT MODEL (BASED ON XN-75-41)

ANGLE OF INJECTION	ΔP PENALTY WITH ACC.	ΔP PENALTY WITH PUMP
90°	1.8	0.8
75°	1.5	0.35
60°	0.4	0.35
45°	0.6	0.30

0 XN-NF-78-30 MODEL

- BASED ON 1/14 AND 1/3 SCALE TEST
- ΔP = 0.15 PSID
- GENERIC APPROVAL SER 3/30/79

0 ΔP = 0.15 PSID APPLICABLE TO YP

Cycle 18 Analysis

Want

- Avoid Power Derate
- Avoid Unwarranted Operating Restrictions
- SER Before Planned Plant Startup

Need

- Near Term Model Changes
  - Injection ΔP Penalty
  - Statistical Combination of Uncertainties
- Use of Nominal Power Shapes
- Change in F_{XE} and F_I Tech. Spec.

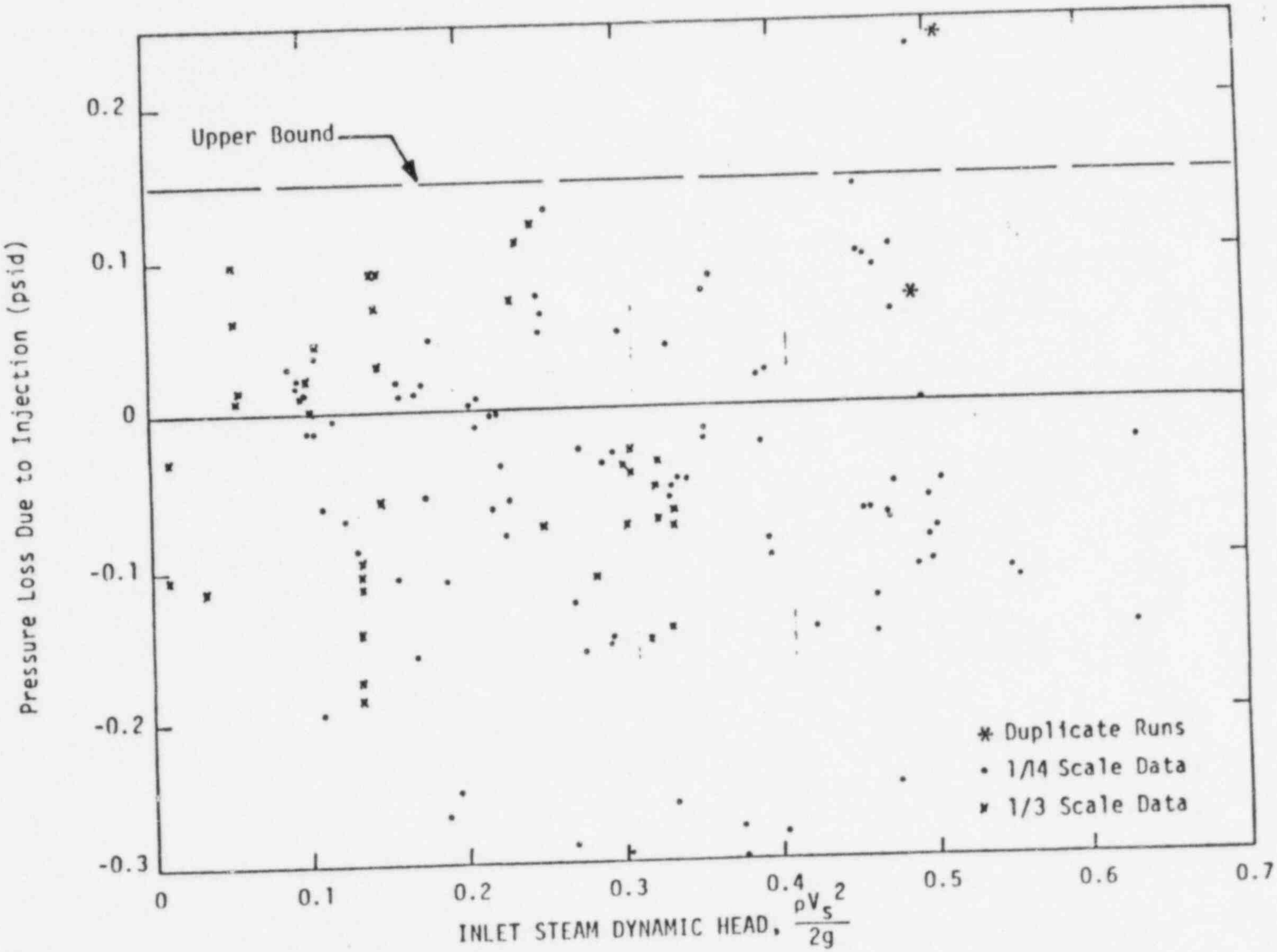


FIGURE 2.3 PRESSURE LOSS DUE TO PUMPED SAFETY INJECTION