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USA/FBR PROGRAM FAST FLUX TEST FACILITY STARTUP PHYSICS AND REACTOR CHARACTERIZATION METHODS AND RESULTS

R. A. Bennett

R.A. Harris

J.W. Daughtry

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SYNOPSIS

USA/FBR PROGRAM FAST FLUX TEST FACILITY

STARTUP PHYSICS AND REACTOR CHARACTERIZATION METHODS AND RESULTS

Development of sodium-cooled Fast Breeder Reactor fuels, controls and materials, and gaining experience with equipment, are the primary goals of testing in the USA Fast Flux Test Facility. Two essential activities supporting those goals are the development of safe and efficient operating methods for assessing the physics of the reactor on a cycle-by-cycle basis and the development of a neutronics and thermal/hydraulics data base necessary to characterize the testing environment within the reactor core.

Specific development activities began in the late 1960's with the beginning of nuclear critical experiments in the US Zero Power Reactor III (ZPR III). That critical assembly work ended in 1974 with a simulation of the initial loading-to-critical of FTR in an engineering mockup in ZPR IX of the final design of FTR.

Final confirmation of much of the engineering mockup work has been achieved in FTR zero-power experiments in February, 1980, and in power demonstration performed in December, 1980, and March, 1981. Final in-core low-power and high-power irradiation of spatially distributed radioactivants will be completed late in 1981. This paper will describe physics experiments and present summaries of the extensive results accumulated to date.

Specific experimental efforts to be discussed have been grouped:

1. Initial fuel loading and approach-to-criticality, experimental confirmation of control rod worths, shutdown reactivity margins, inverse kinetics reactivity assessment methods, modified source multiplication subcritical reactivity monitoring, and isothermal temperature coefficient and flow effect measurements.

2. In-core measurements of proton recoil spectra for neutron spectra inference, in-core active measurements of the absolute fission rates of ^{239}Pu, ^{235}U, etc., axial active measurements of fission and capture rate distributions, in-core measurements of gamma ray spectra, and in-core measurements of gamma ray energy deposition rates.

All of the above experiments were conducted in a cryogenically nitrogen gas-cooled stainless steel thermos bottle inserted in a Row 2 re-entrant thimble, called an In-Reactor Thimble (IRT). Experimental apparatus was installed in the thermos bottle from the manned operating deck of the reactor containment building. Electronics for the active experiments were located on that same deck.

3. Power ascent measurements of power defect, reactivity anomoalies, power coefficients, and source buildup with exposure were carried out during the initial power demonstration run in December, 1980.

As the power of FFTF was raised, the power reactivity defect was inferred from the positions of the control rods; power coefficients were similarly determined and found to decrease with increasing power. Reactivity anomalies, the difference between expected and observed system reactivity, was monitored frequently during a number of ascents and descents in power. Variations observed indicated some inaccuracies in reactivity feedback models. The inherent neutron source of plutonium-fueled systems increases with fuel age and impacts the accuracy of subcritical reactivity measurements. This buildup has been monitored during the first 20 full-power days of operation and was found to be greater than expected by about 20%. Reactor stability has been confirmed by rod drop techniques.

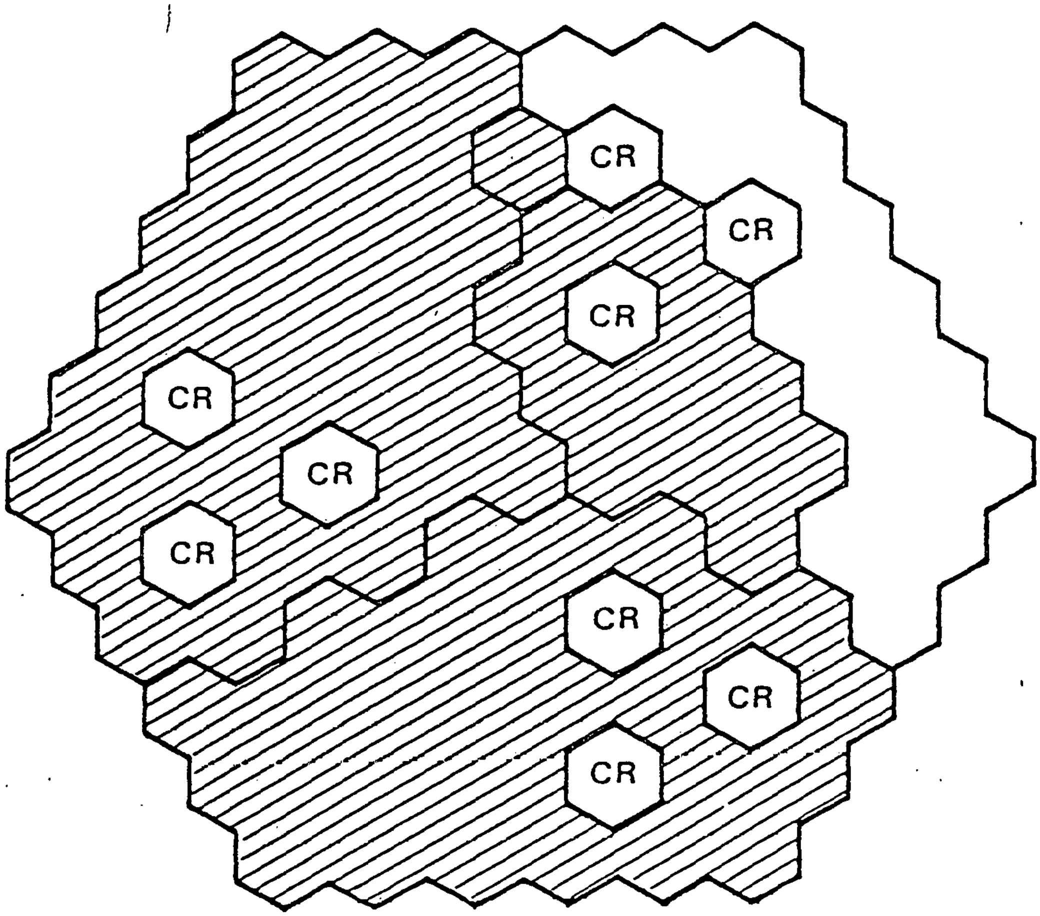
4. Passive measurements of the spatial distributions of neutron reaction rates within the core fuel pins and pin bundles have recently begun. Fissile, fertile, and capture radioactivants are being irradiated at both low power (approximately 4 Mw for 1 day) and high power (approximately 400 Mw for 8 days). Axial distributions of reactions are to be measured with subassemblies placed in 21 selected radial core positions. Three positions are duplicated to provide an absolute intertie between the low-power and high-power irradiations.

5. For fuel and test management and support of postirradiation examination of tests, the physics of FFTF operation will be monitored closely. Power history control configuration, burnup of fuel and poison elements, and thermal/hydraulics are to be monitored. Physical measurements related to core component distortion will be made to aid in evaluation feedback effects. Bowing is expected to be significant, although little, if any, effect has been observed in the first 20 days of full-power operation.

USA FBR Program Fast Flux Test Facility
Startup Physics and Reactor Characterization Methods and Results

(Copies of Vu-Graphs)

INITIAL-CRITICAL LOADING



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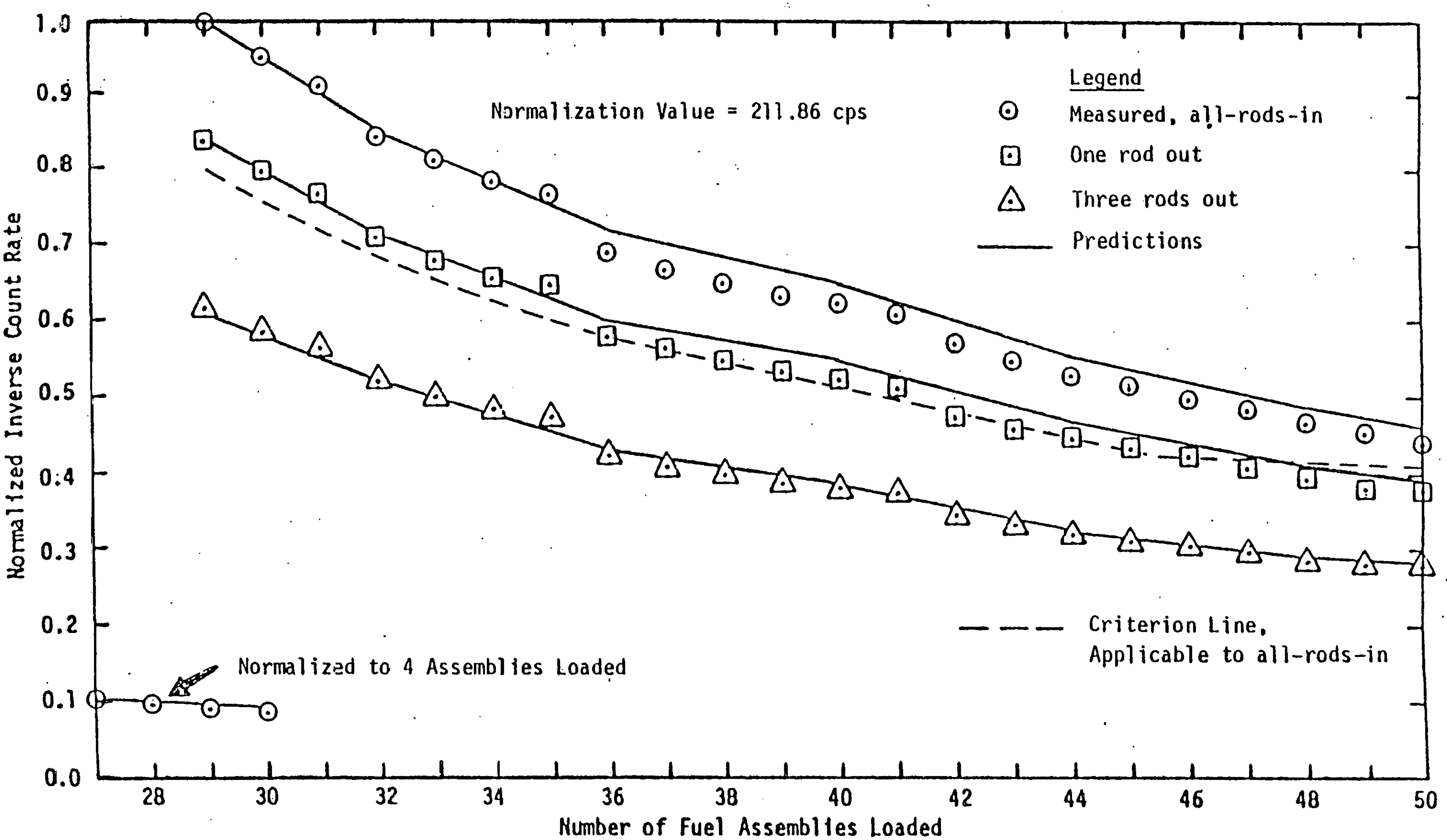


Figure 12. Inverse Count Rate vs. Fuel Assemblies Loaded in Second Trisector - IRT Middle.

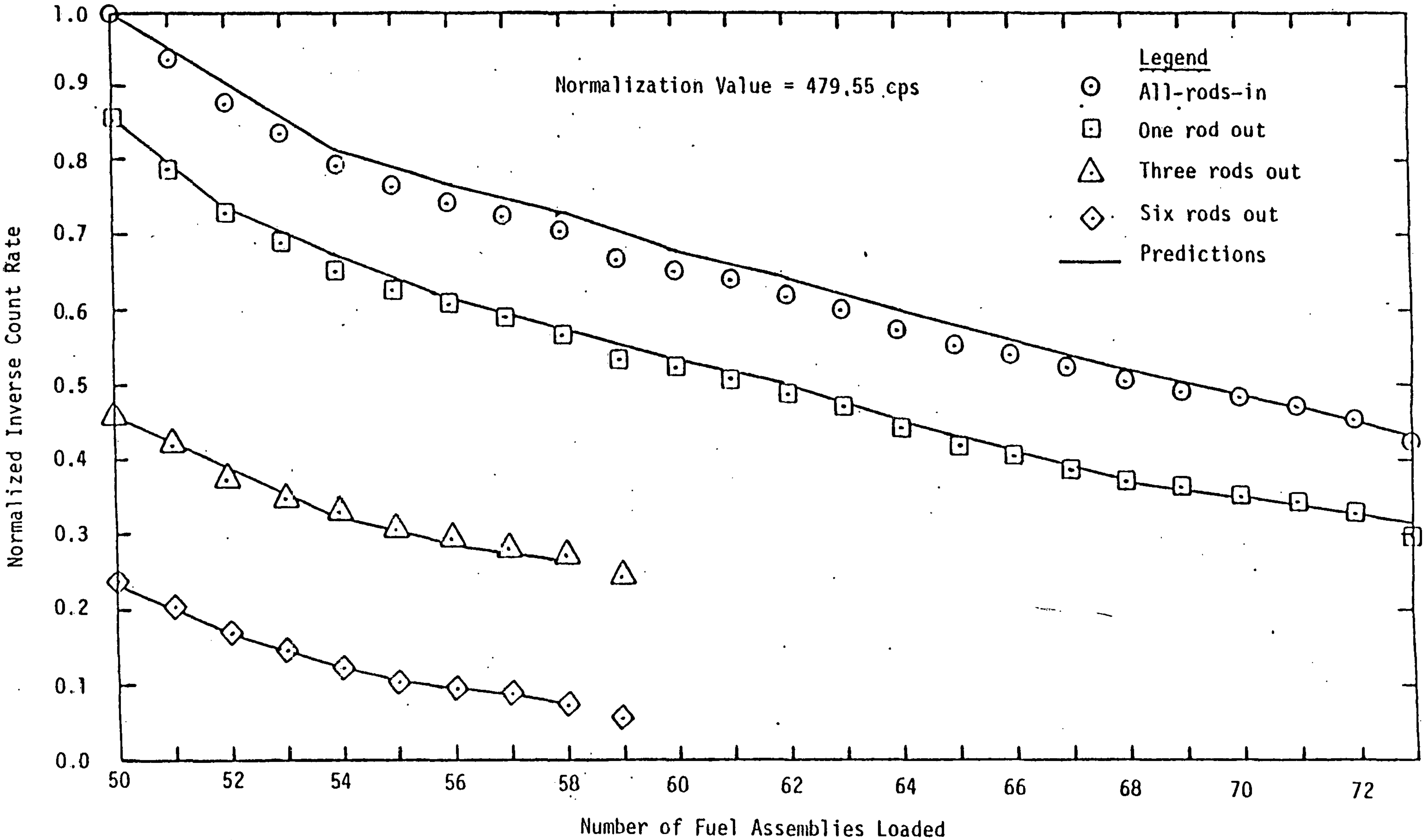
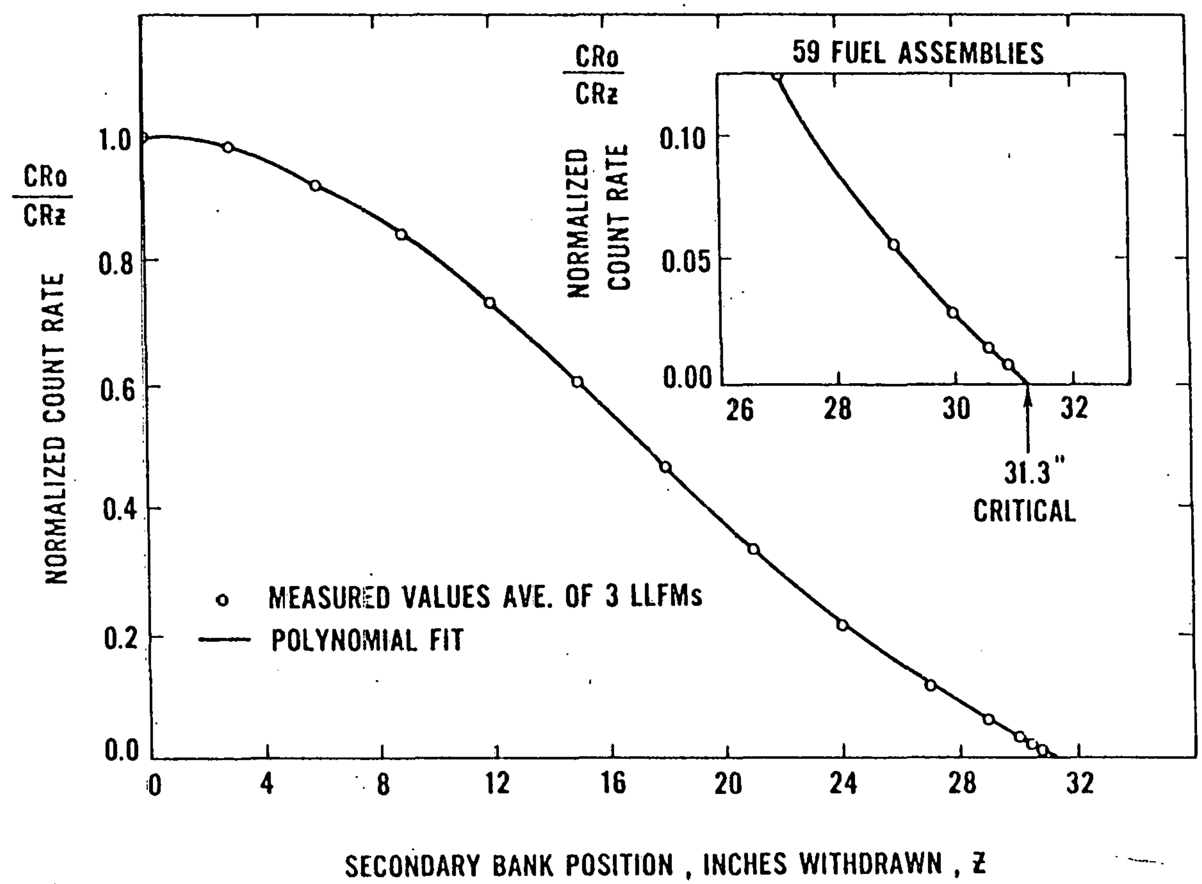


Figure 19. Inverse Count Rate vs. Fuel Assemblies Loaded in Third Trisector - IRT Middle.

FFTF INITIAL APPROACH-TO-CRITICAL FEB. 9, 1980



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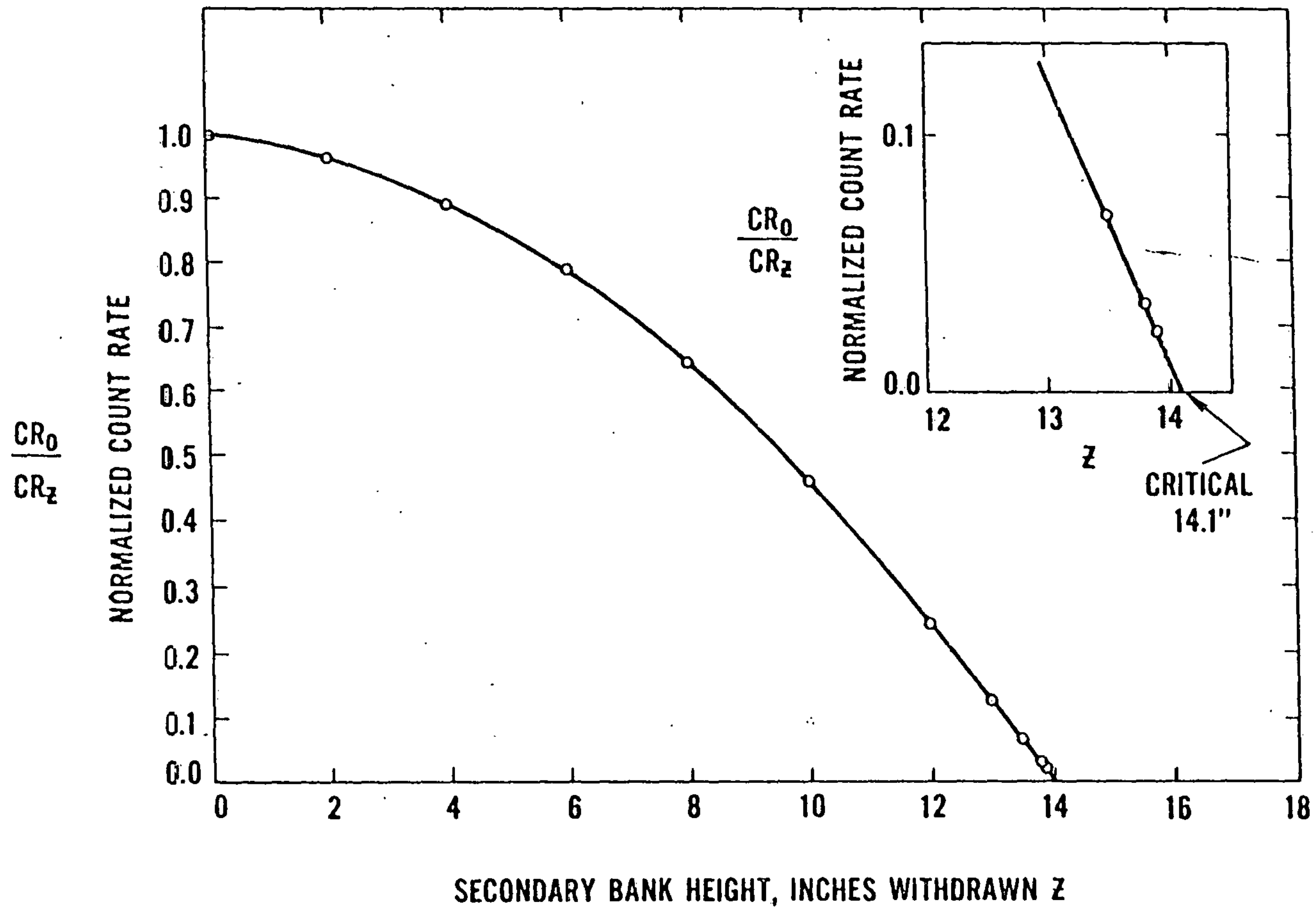
FFTF APPROACH-TO-CRITICAL 73 FUEL ASSEMBIES (FULL CORE) MARCH 8, 1980



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CORE PHYSICS MEASUREMENTS

- o OPERATIONAL PHYSICS TESTS
- o CHARACTERIZATION TESTS

CHARACTERIZATION MEASUREMENTS

- NEUTRONIC
- GAMMA
- THERMAL-HYDRAULIC
- VIBRATION

TEST VEHICLES

- IN-REACTOR THIMBLE - IRT
- VIBRATION OPEN TEST ASSEMBLY - VOTA
- CHARACTERIZER ASSEMBLIES
- IN-VESSEL STORAGE SAMPLE HOLDERS - IVS-SH
- REACTOR CAVITY CONDUIT
- REACTOR INSTRUMENTATION
  - FLOWMETERS
  - TEMPERATURE MEASURING DEVICES
  - LOW LEVEL FLUX MONITORS - LLFMs
  - EX-VESSEL FLUX MONITORS
- FUEL ASSEMBLIES - PIGGYBACK FIRST CYCLE DRIVER EXAMINATION PROGRAM

GAMMA MEASUREMENTS

PARAMETER	METHODS: ACTIVE	METHODS: PASSIVE
GAMMA SPECTRUM	COMPTON RECOIL SPECTROMETER (IRT)	
GAMMA DOSE, DOSE RATE	IONIZATION CHAMBERS (IRT) (VOTA) SELF-POWERED DETECTORS (VOTA)	THERMOLUMINESCENT DETECTORS (IRT)
GAMMA ENERGY DEPOSITION	CALORIMETERS (IRT) (VOTA)	THERMAL EXPANSION DETECTORS (CHARACTERIZERS)

NEUTRONIC MEASUREMENTS

- NEUTRON SPECTRA
- FISSION RATES
- U AND PU CAPTURE RATES
- OTHER REACTION RATES OF INTEREST

FISSION RATES

MEASUREMENT PLAN

1. IRT
   - ABSOLUTE FISSION RATES BY NBS AFC
   - AXIAL TRAVERSE BY MINIATURE CHAMBER
   - SSTR-FISSION FOIL-AFC COMPARISON AND CALIBRATION

2. LP TEST
   - SSTR AND FISSION FOILS IN ELEVEN CHARACTERIZERS
   - FUEL PIN GAMMA SCAN

3. HP TEST
   - SSTR AND FISSION FOILS IN ELEVEN CHARACTERIZERS
   - SSTR AND FISSION FOILS IN TWO IVS LOCATIONS
   - FUEL PIN GAMMA SCAN
   - FUEL PIN DESTRUCTIVE ASSAY
   - SUMMATION METHOD

4. FIRST CYCLE (TWO ASSEMBLIES)
   - FUEL PIN GAMMA SCAN
   - FUEL PIN DESTRUCTIVE ASSAY

NEUTRON SPECTRUM MEASUREMENTS

TECHNIQUES:

1. PROTON RECOIL PROPORTIONAL COUNTERS $5keV < E_n < 2MeV$
2. PROTON RECOIL EMULSIONS $.8MeV < E_n < 10MeV$
3. PASSIVE DOSIMETRY + DATA ADJUSTMENT $1eV < E_n < 15MeV$

ACCURATE VALUES REQUIRED FOR:

- VERIFICATION OF REACTOR PHYSICS CODE USE
- CALCULATION OF ALL INTEGRAL REACTOR QUANTITIES, SUCH AS FAST FLUX (F) $= \int_{.1MeV}^{\infty} \phi(E,\vec{r})dE$

  REACTION RATE (F) $\propto \int \phi(E,\vec{r}) \quad (E)dE$

  TOTAL FLUX (F) $= \int \phi(E,F)\, dE$

  TOTAL FISSION POWER $\propto \int_F \int_E \phi(E,\vec{r})\, \Sigma_f\, (E,\vec{r})dE\, dT$

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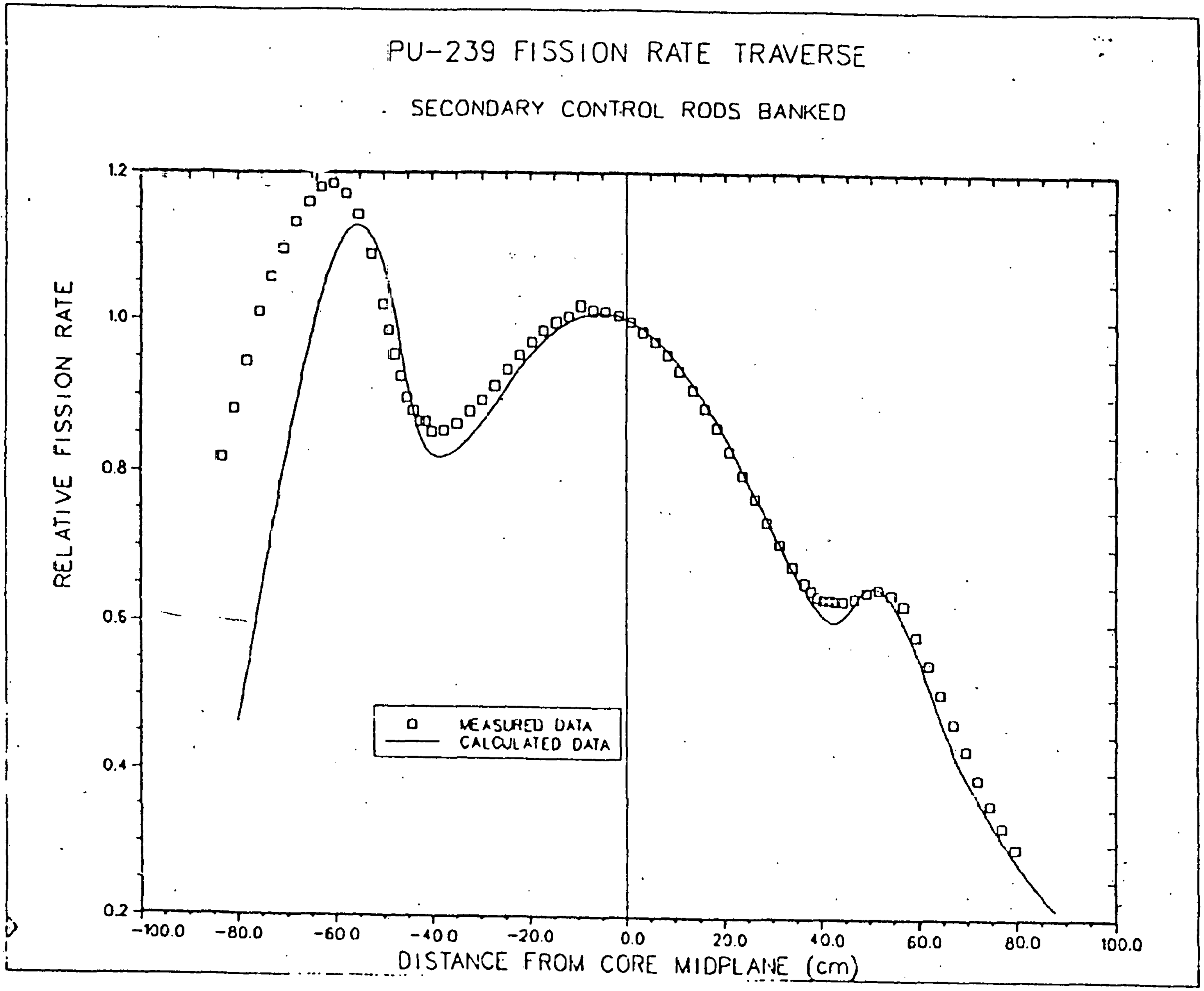
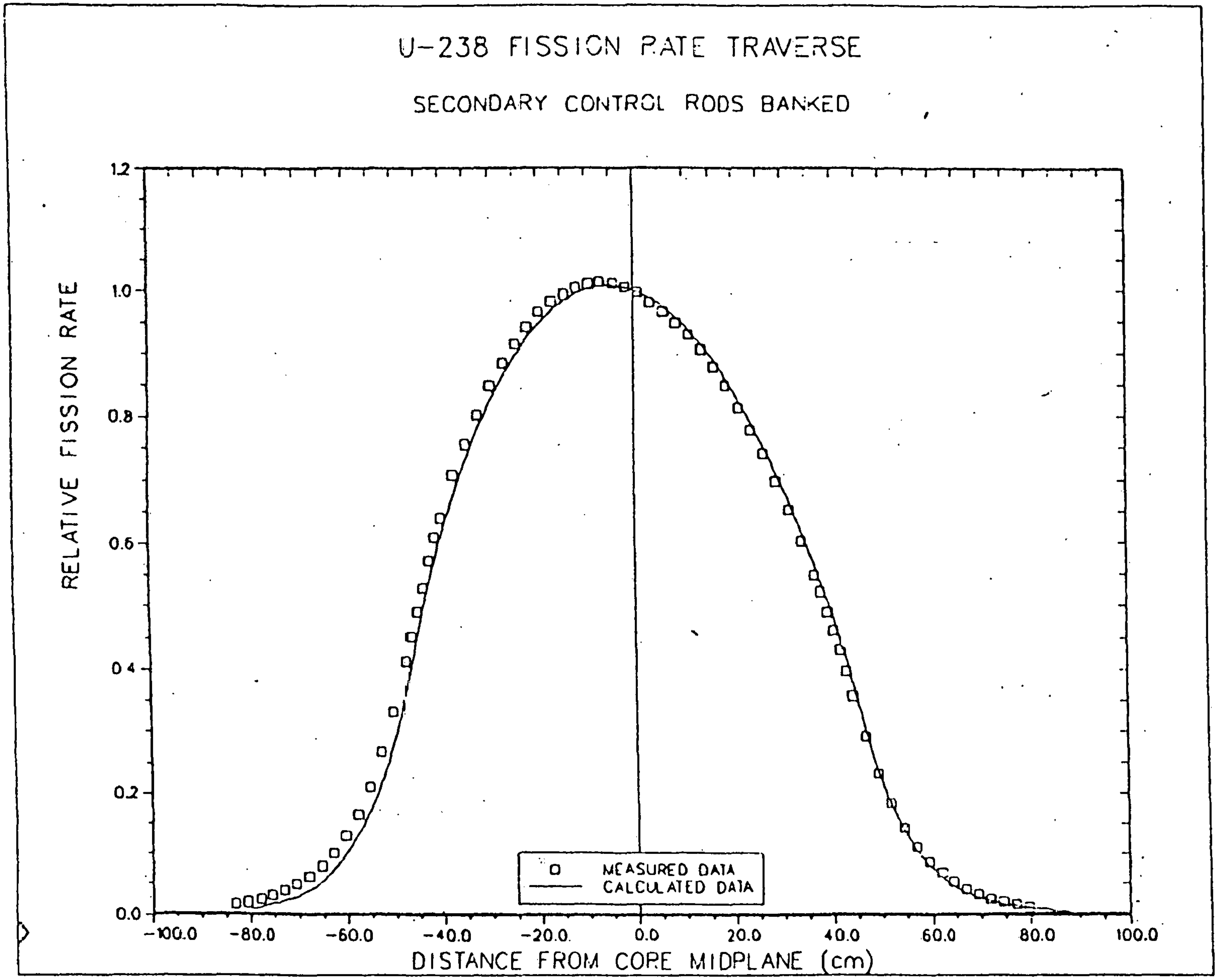
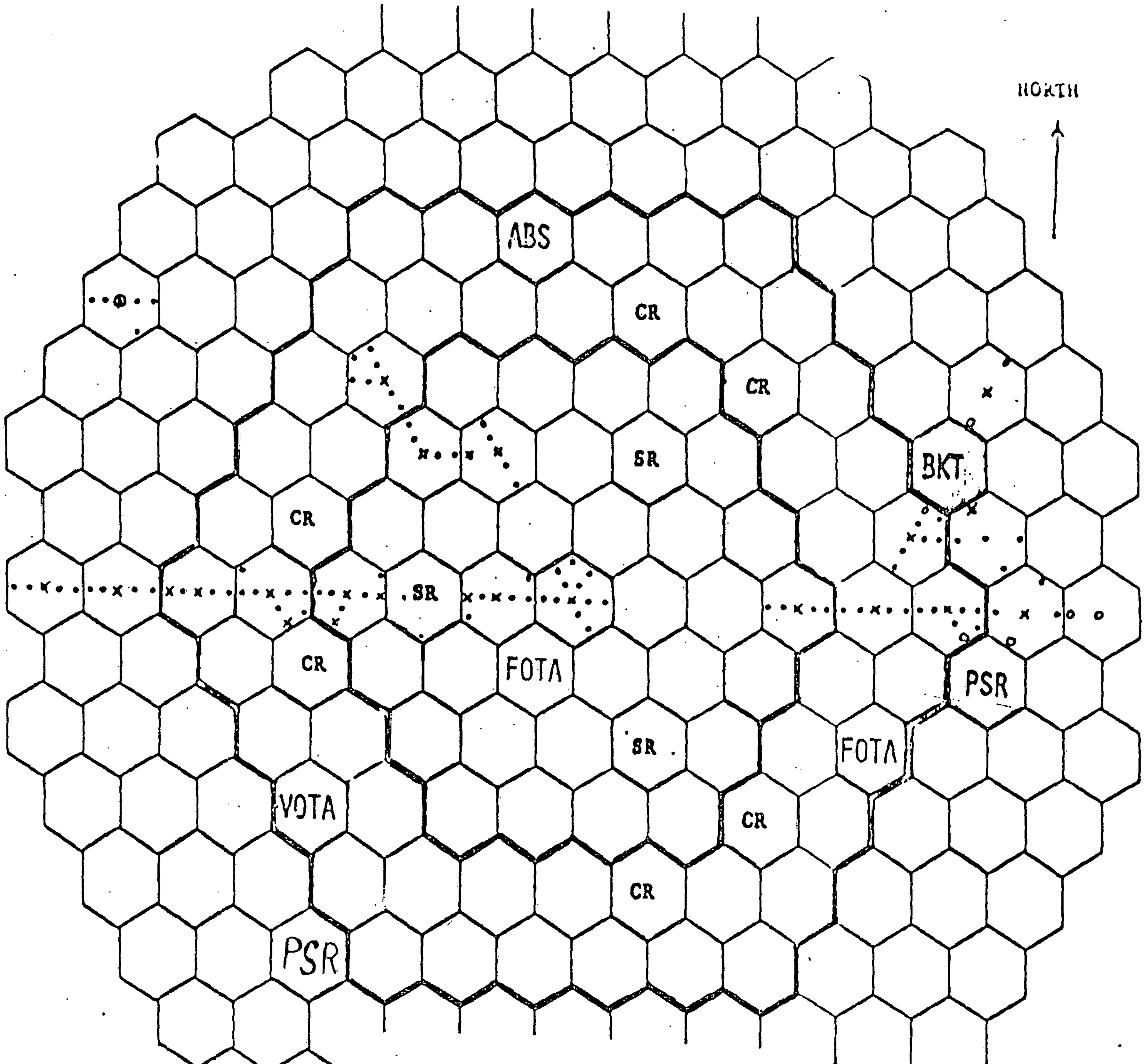

PU-239 FISSION RATE TRAVERSE
SECONDARY CONTROL RODS BANKED
RELATIVE FISSION RATE
1.2
1.0
0.8
0.6
0.4
0.2
-100.0
-80.0
-60.0
-40.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
DISTANCE FROM CORE MIDPLANE (cm)
MEASURED DATA
CALCULATED DATA



U-238 FISSION RATE TRAVERSE
SECONDARY CONTROL RODS BANKED
RELATIVE FISSION RATE
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-100.0
-80.0
-60.0
-40.0
-20.0
0.0
20.0
40.0
60.0
80.0
100.0
DISTANCE FROM CORE MIDPLANE (cm)
MEASURED DATA
CALCULATED DATA



CHARACTERIZER PIN LOCATIONS

OPERATIONAL PHYSICS TESTS

CATEGORIES:

- TECHNICAL SPECIFICATION COMPLIANCE
- VERIFY ALTERNATE TESTING TECHNIQUES
- EVALUATE ACCURACY AND REPEATABILITY
- OBTAIN ACCURATE DATA BASE
- VERIFY CALCULATIONAL MODELS FOR FUEL MANAGEMENT AND ATYPICAL OPERATION

ZERO POWER PHYSICS TESTS PERFORMED AFTER CORE LOADING

- REACTIVITY COMPARISONS - INVERSE KINETICS ROD DROP (IKRD) VS. MODIFIED SOURCE MULTIPLICATION (MSM).
- FULL SHUTDOWN REACTIVITY ASSESSMENTS.
- TOTAL WORTH OF PRIMARY RODS.
- TOTAL WORTH OF SECONDARY RODS.
- INDIVIDUAL ROD WORTHS.
- MAXIMUM REACTIVITY ADDITION RATE.
- PRIMARY SYSTEM SHUTDOWN MARGIN.
- SECONDARY SYSTEM SHUTDOWN MARGIN.
- EXCESS REACTIVITY.
- ISOTHERMAL TEMPERATURE COEFFICIENT OF REACTIVITY.
- FLOW EFFECT ON REACTIVITY.

CONTROL ROD WORTH MEASUREMENTS

ROD #	CALCULATED WORTH	EXPERIMENTAL WORTH	C/E
1	$5.77	$5.82 ± .08	.992
2	5.50	5.52 ± .07	.997
3	5.42	5.40 ± .06	1.004
4		4.07 ±	
5	4.06	4.09 ± .05	.992
6		3.57 ± .04	
7	3.86	3.86 ±	.999
8		3.17 ± .03	
9	3.77	3.83 ±	.985
1&2		11.22 ± .10	

FTR/EMC (AVG. OF MANY MEASUREMENTS), ADJUSTED TO ENDF/B-IV ΔN DATA. 0.997 ± .025

REACTIVITY VALUES

FULLY LOADED CORE

73 FUEL ASSEMBLIES

PRIMARY RODS	REACTIVITY, $	COMMENT
PR-1	5.82 ± 0.04	SECONDARY BANK
PR-2	5.52 ± 0.07	AT 13.9"
PR-3	5.40 ± 0.06	
PRIMARY BANK	16.34 ± 0.12	SECONDARY BANK FULLY INSERTED
PRIMARY SYSTEM SHUTDOWN MARGIN	8.06 ± 0.66	MUST EXCEED HIGHEST SECONDARY ROD WORTH

REACTIVITY VALUES

FULLY LOADED CORE

73 FUEL ASSEMBLIES

SECONDARY RODS	REACTIVITY, $	COMMENT
SR-4	4.07 ± 0.04	PRIMARIES OUT,
SR-5	4.09 ± 0.05	SECONDARIES BANKED
SR-6	3.57 ± 0.04	" "
SR-7	3.86 ± 0.06	" "
SR-8	3.17 ± 0.07	" "
SR-9	3.83 ± 0.04	" "
SECONDARY BANK	19.94 ± 0.10	PRIMARIES IN
	21.98	PRIMARIES OUT
SECONDARY SYSTEM SHUTDOWN MARGIN	7.32	@ 400°F
	8.52	@ 592°F
EXCESS REACTIVITY	14.66	@ 400°F
	13.96	@ 592°F
	11.50	@ FULL POWER

INITIAL POWER ASCENT PHYSICS TESTS

TEST	0	5	10	15	25	35	40	50	65	75	100
REACTIVITY SURVEILLANCE - MSM	X										
REACTIVITY SURVEILLANCE - ANOMALY DETECTION CALIBRATION	X		X			X				X	X
REACTIVITY SURVEILLANCE - ANOMALY DETECTION CHARACTERIZATION											X
POWER CALIBRATION	X										
TEMPERATURE COEFFICIENT	X										
POWER COEFFICIENT		X		X	X	X	X	X	X	X	X
STABILITY	X			X		X				X	

NATURAL CIRCULATION POWER ASCENT PHYSICS TESTS

TEST	POWER, %											
	0	2	5	15	25	35	40	50	65	75	90	100
REACTIVITY SURVEILLANCE	X											
NEUTRON SOURCE BUILDUP	X											
PSSM	X											
SSSM	X											
CONTROL ROD CALIB. BY RUN-IN	X											
ROD SEGMENT WORTH COMPARISON, IKRD AND POSITIVE PERIOD	X											
ROD WORTHS IN TILTED FLUX	X											
TEMPERATURE COEFFICIENT	X											
EXCESS REACTIVITY		X										
POWER COEFFICIENT			X	X	X	X	X	X	X	X	X	X
STABILITY	X					X						X

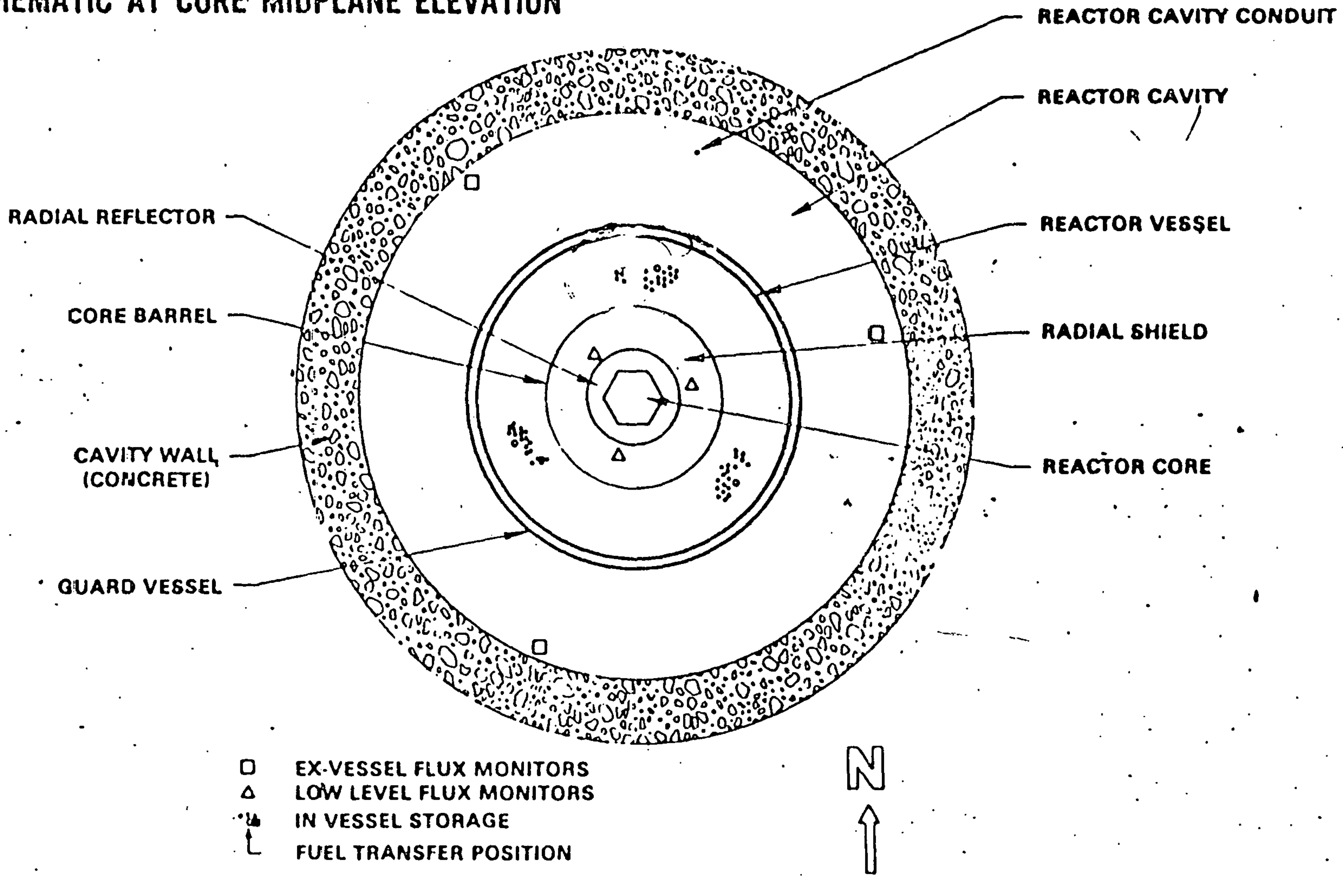
EXCESS REACTIVITY

CONDITION	MEASURED, $	PREDICTED, (PDN) $	M-P, $
440°F	15.1[†]	15.4	-0.3
595°F (HOT STANDBY)	14.2[*]	14.6	-0.4
100% POWER	11.1[*]	11.3	-0.2

†BASED ON CRITICAL POSITION AT 443°F

*BASED ON A MEASUREMENT AT 2% POWER

FFTF SCHEMATIC AT CORE MIDPLANE ELEVATION



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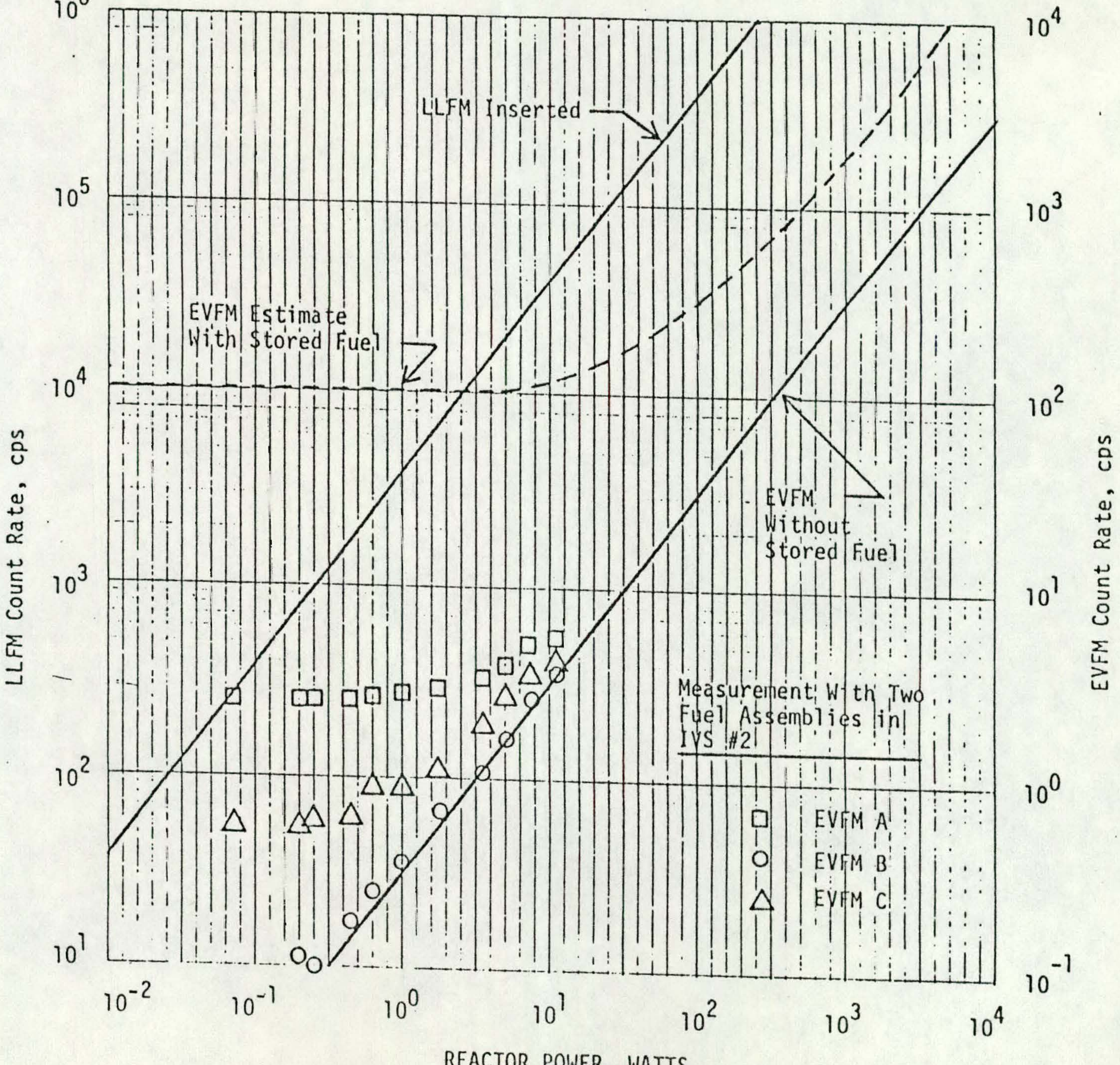
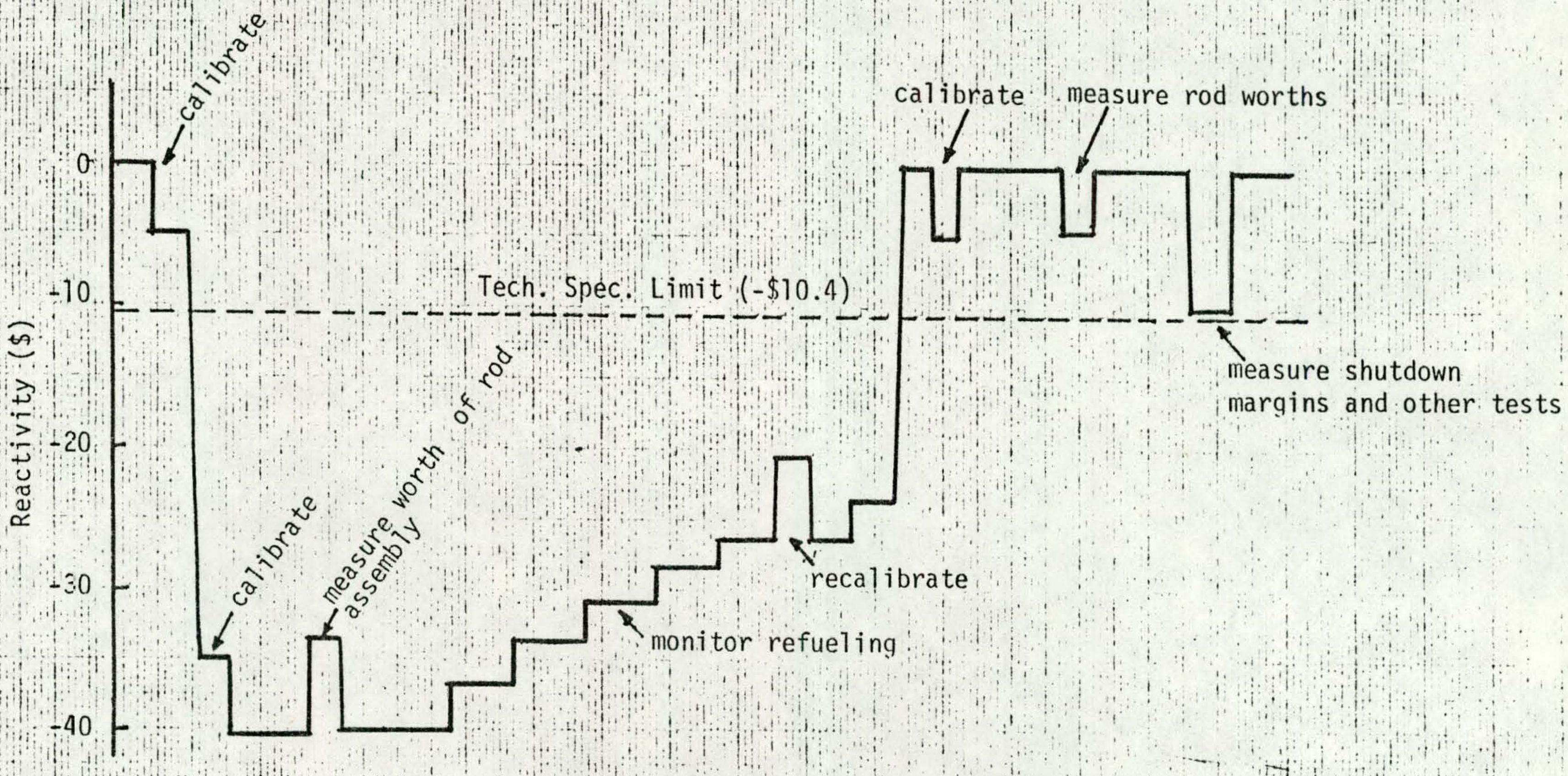
DETECTOR RESPONSE TO REACTOR POWER



<u>GENERAL AREAS OF REACTIVITY MONITORING</u>

- SUBCRITICAL (MSM AND INVERSE KINETICS ROD DROP)
- ANOMALY DETECTION
- STABILITY AND REACTIVITY COEFFICIENTS



Subcritical Reactivity Monitoring

SUBCRITICAL MONITORING REQUIREMENTS

- CALIBRATION OF MSM NEAR CRITICAL TO -$10.4
- REACTIVITY AND WORTHS FULL SHUTDOWN
- NEUTRON SOURCE BUILDUP AND DECAY
- NEUTRON SOURCE REMOVAL

MSM CALIBRATION CONSTANTS

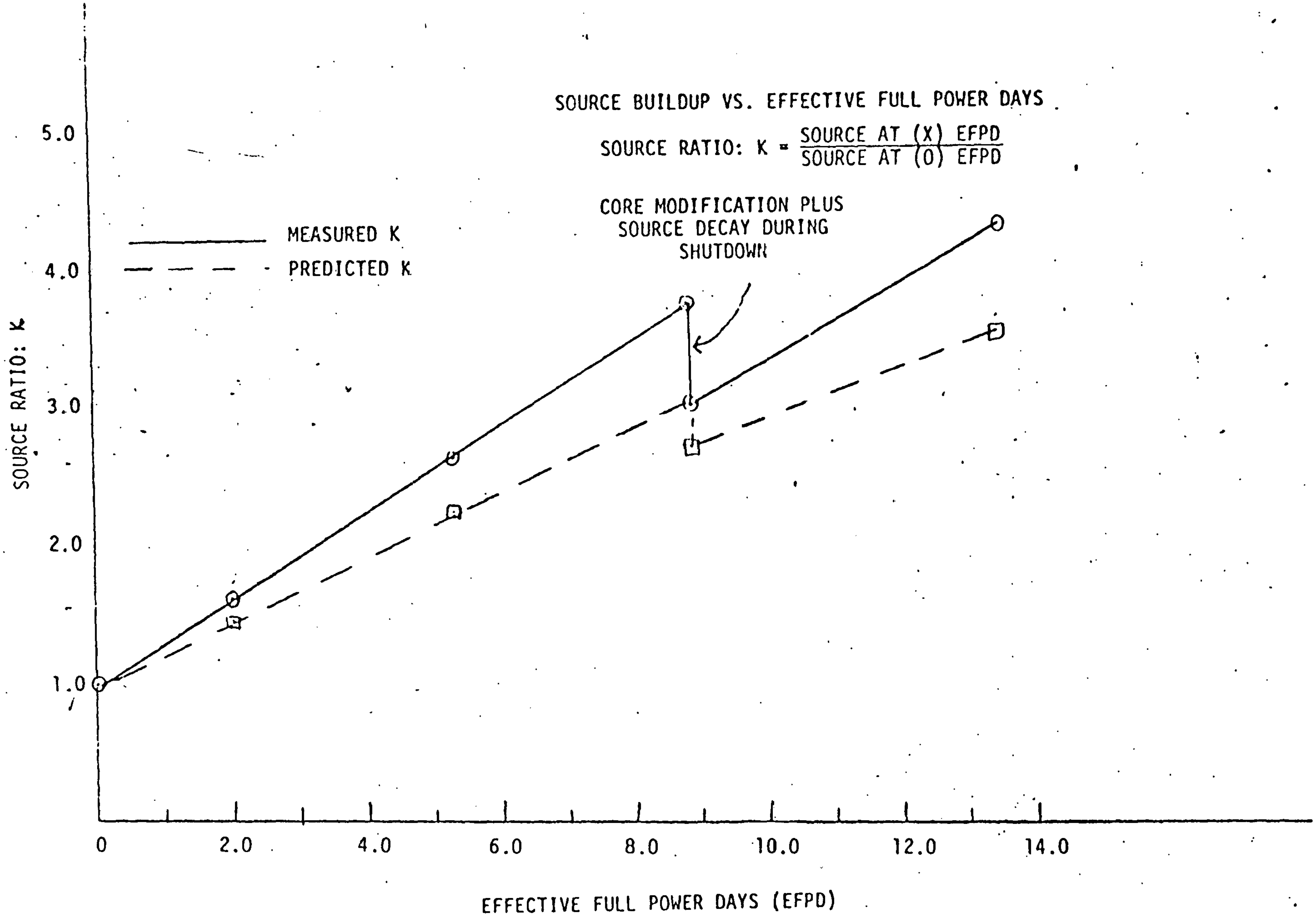
ROD DROPPED	$Q_N/\bar{Q}_N$ LLFM-A	LLFM-B	LLFM-C	AVERAGE
(SECONDARY CONTROL RODS BANKED)				
SR-1	0.985	1.009	0.993	0.996
SR-2	1.010	0.966	1.002	0.993
SR-3	0.966	0.990	1.006	0.987
(SECONDARY CONTROL RODS 5, 7 OUT; 4, 6, 8, 9 INSERTED)				
CR-7	0.999	0.992	0.991	0.994
CR-5	1.021	1.011	1.003	1.012
SR-1	0.993	1.007	0.988	0.996
SR-2	1.026	1.027	0.994	1.016
SR-3	1.001	0.996	1.024	1.007
$\sigma(Q_N/\bar{Q}_N)$	0.019	0.018	0.012	0.010
EXPERIMENT σ(%)	1.3-1.8	1.6-2.2	1.3-1.6	
AVERAGE CONSTANTS ($\bar{Q}_N$ IN $-CPS)	4613.6	3156.3	4396.4	

MSM CALIBRATION CONSTANTS
(CONTINUED)

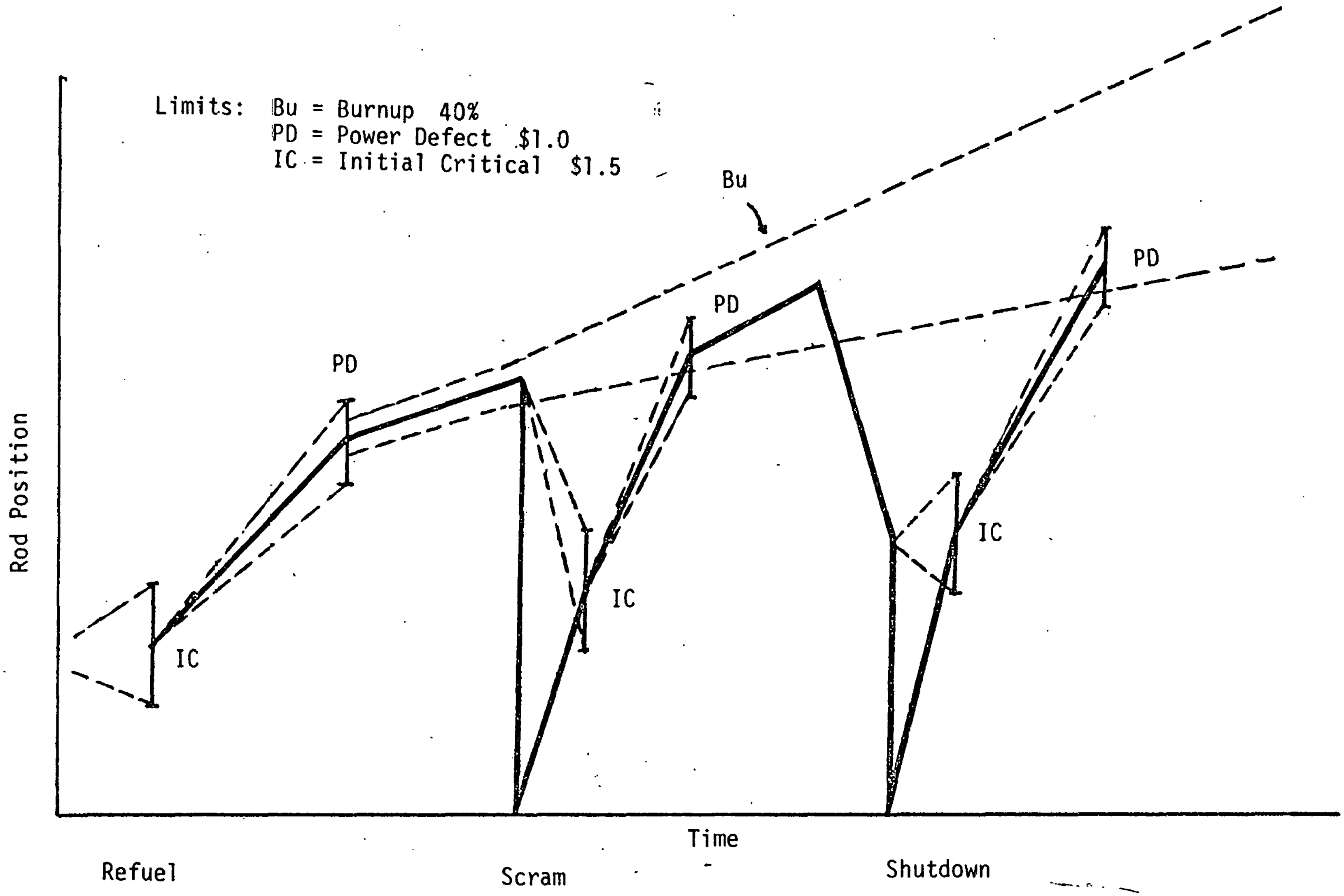
ROD DROPPED	$Q_N/\bar{Q}_N$			
	LLFM-A	LLFM-B	LLFM-C	AVERAGE
(SECONDARY CONTROL RODS 5, 7 OUT; 4, 6, 8, 9 INSERTED)				
CR-5, SR-1	0.985	1.038	0.992	1.005
CR-5, SR-2	0.998	1.004	1.000	1.001
SR-1, SR-2	1.051	1.013	1.022	1.029
SR-1, SR-3	1.019	1.013	1.014	1.015
CR-5, SR-1, SR-2	1.066	1.038	1.022	1.042
CR-5, SR-2, SR-3	1.043	1.001	0.999	1.014
AVERAGE	1.027	1.018	1.008	1.018
	±0.032	±0.016	±0.013	±0.015
EXPERIMENTAL (%)	1.8-2.8	2.3-3.8	1.9-2.5	

DIFFERENTIAL CONTROL ROD WORTHS

ROD	DIFFERENTIAL WORTHS (¢/IN.)		
	MSM	CALCULATED	CALCULATED/MSM
4	15.4 ± 0.20	15.7	1.021 ± 0.013
5	15.7 ± 0.19	15.8	1.004 ± 0.012
6	13.6 ± 0.18	13.8	1.011 ± 0.013
7	14.3 ± 0.19	14.9	1.042 ± 0.013
8	12.1 ± 0.19	12.2	1.009 ± 0.015
9	14.3 ± 0.18	14.8	1.033 ± 0.012



SOURCE BUILDUP VS. EFFECTIVE FULL POWER DAYS
SOURCE RATIO: K = SOURCE AT (X) EFPD / SOURCE AT (0) EFPD
CORE MODIFICATION PLUS SOURCE DECAY DURING SHUTDOWN
MEASURED K
PREDICTED K
SOURCE RATIO: K
5.0
4.0
3.0
2.0
1.0
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
EFFECTIVE FULL POWER DAYS (EFPD)



Reactivity Anomaly Detection

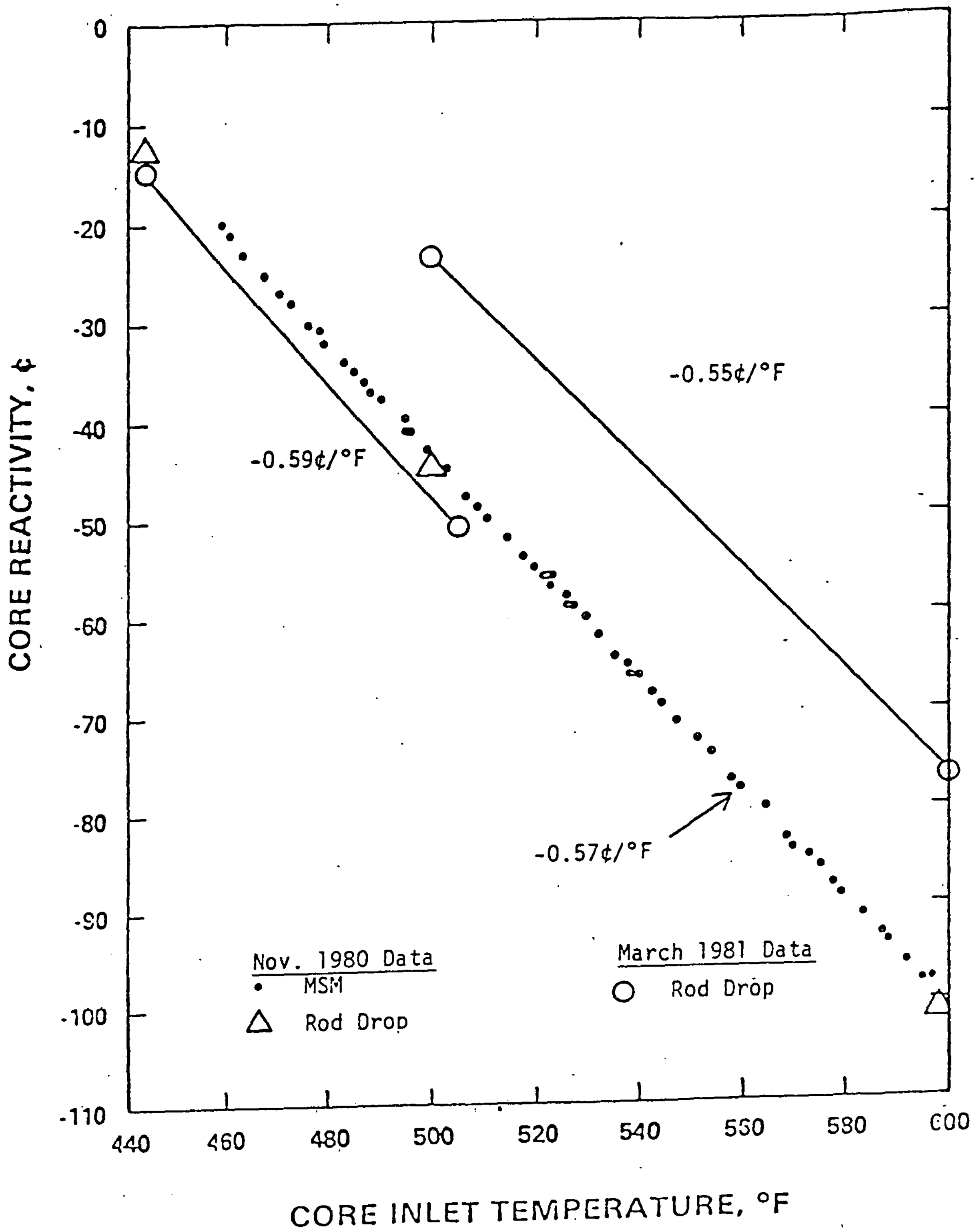
REACTIVITY ANOMALY MONITORING REQUIREMENTS

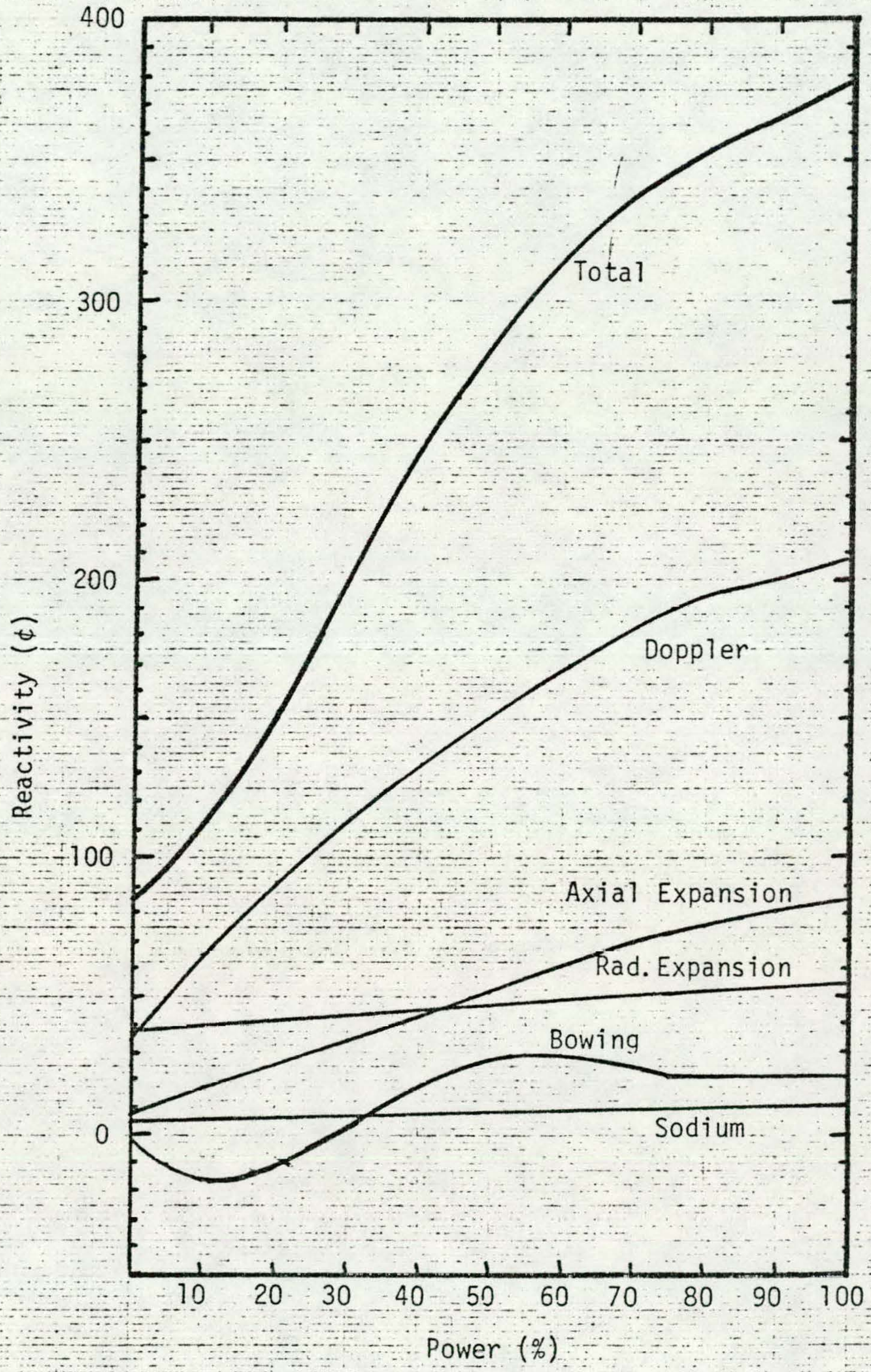
- o VERIFY THAT REACTIVITY FEEDBACKS FALL WITHIN ACCEPTABLE BOUNDS
- o OBTAIN AND MAINTAIN AN ACCURATE DATA BASE
- o DETERMINE THE FUNCTIONAL DEPENDENCE OF PLANT PARAMETER CHANGES
- o DETERMINE THE SENSITIVITY AND REPRODUCIBILITY OF MONITORING TECHNIQUES

NUCLEAR CONTROL AND STABILITY

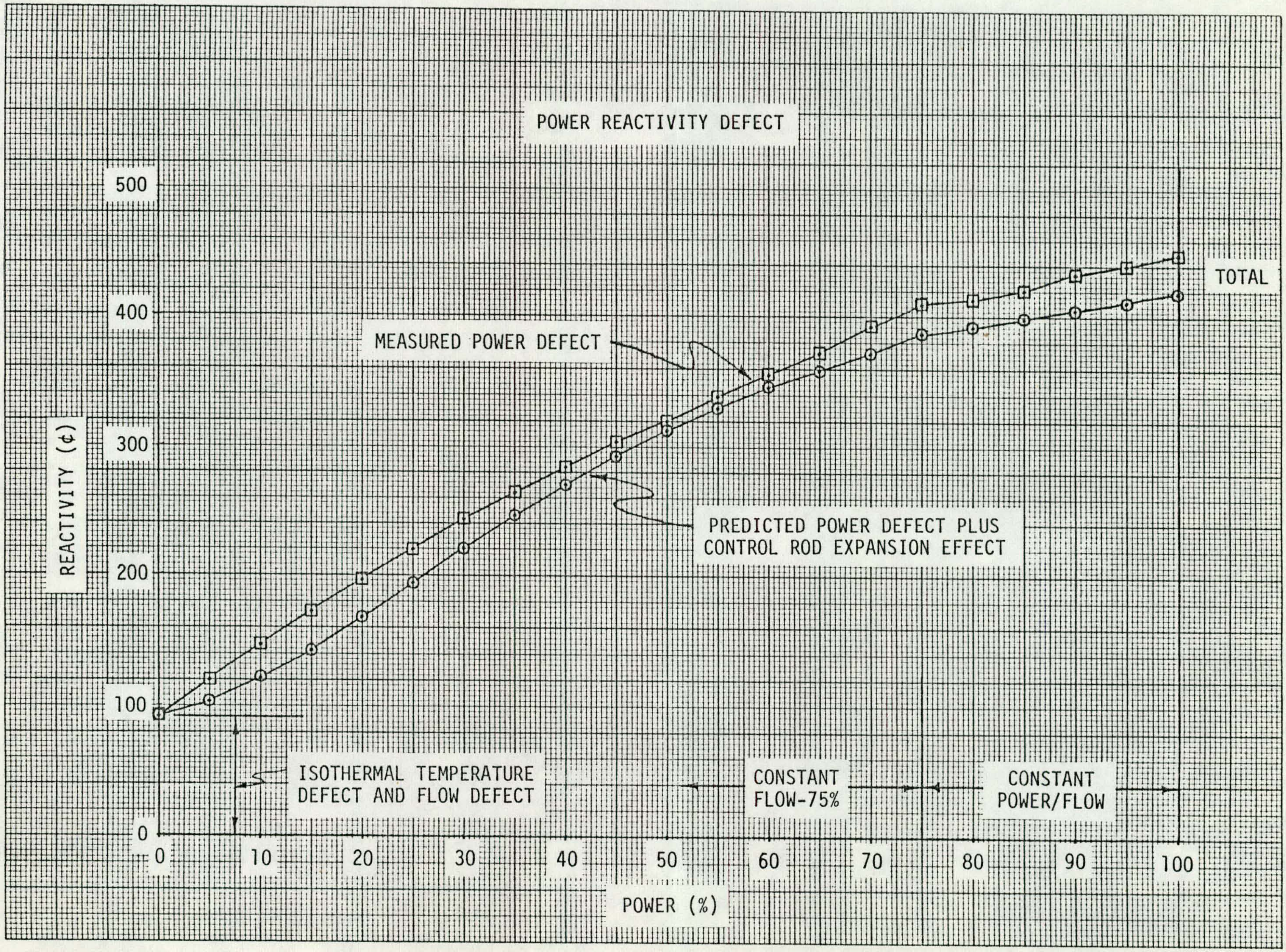
- ISOTHERMAL TEMPERATURE COEFFICIENT IS SUBSTANTIALLY NEGATIVE.
- POWER COEFFICIENT DECREASES IN MAGNITUDE MONOTONICALLY WITH INCREASING POWER AND IS SUBSTANTIALLY NEGATIVE AT ALL POWER LEVELS.
- POWER REACTIVITY DEFECT IS REPRODUCIBLE AND IS IN GENERAL AGREEMENT WITH PREDICTIONS.
- STABILITY PHASE MARGINS ARE LARGE AND REPRODUCIBLE.

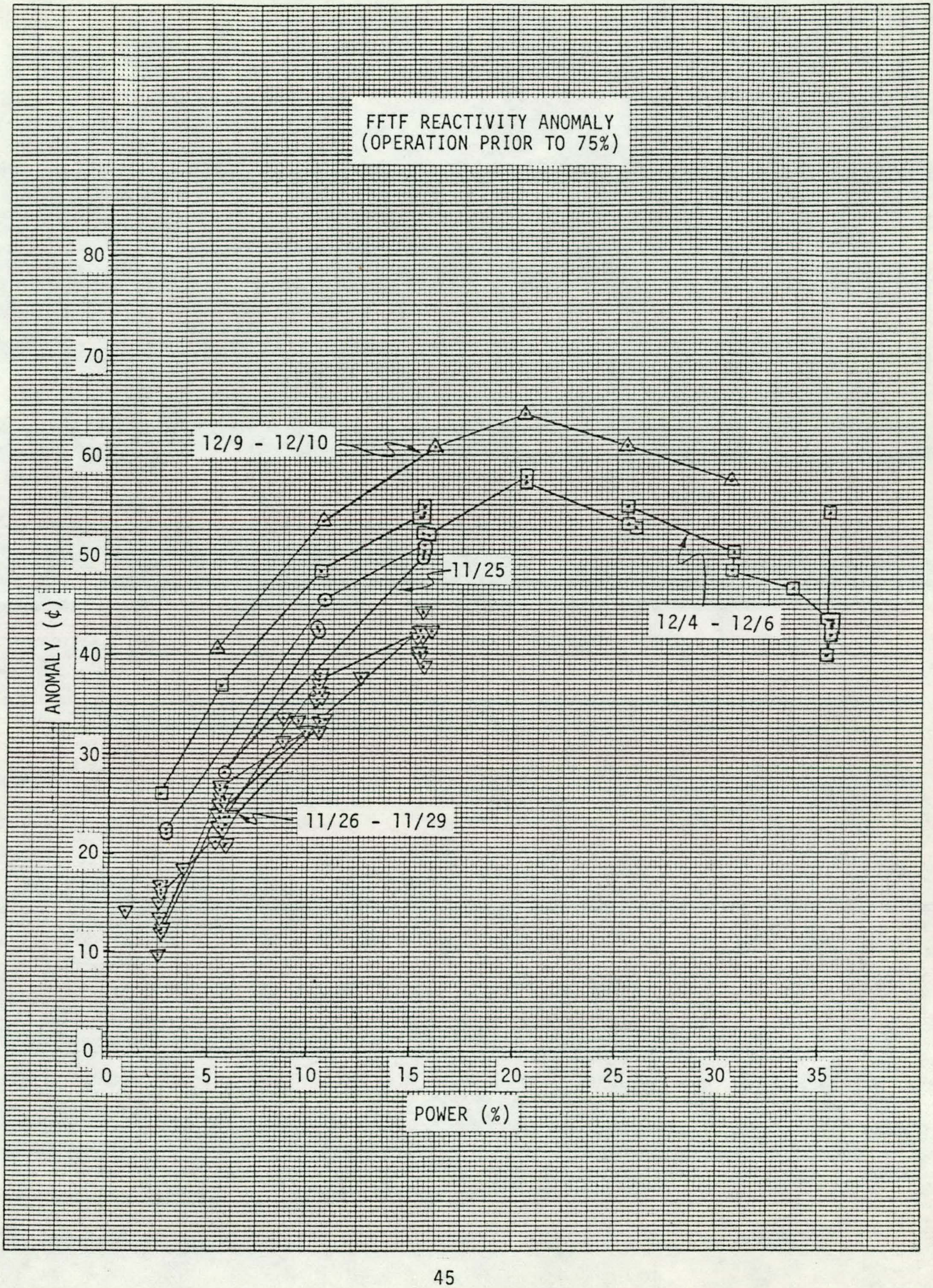
ISOTHERMAL TEMPERATURE COEFFICIENT DATA

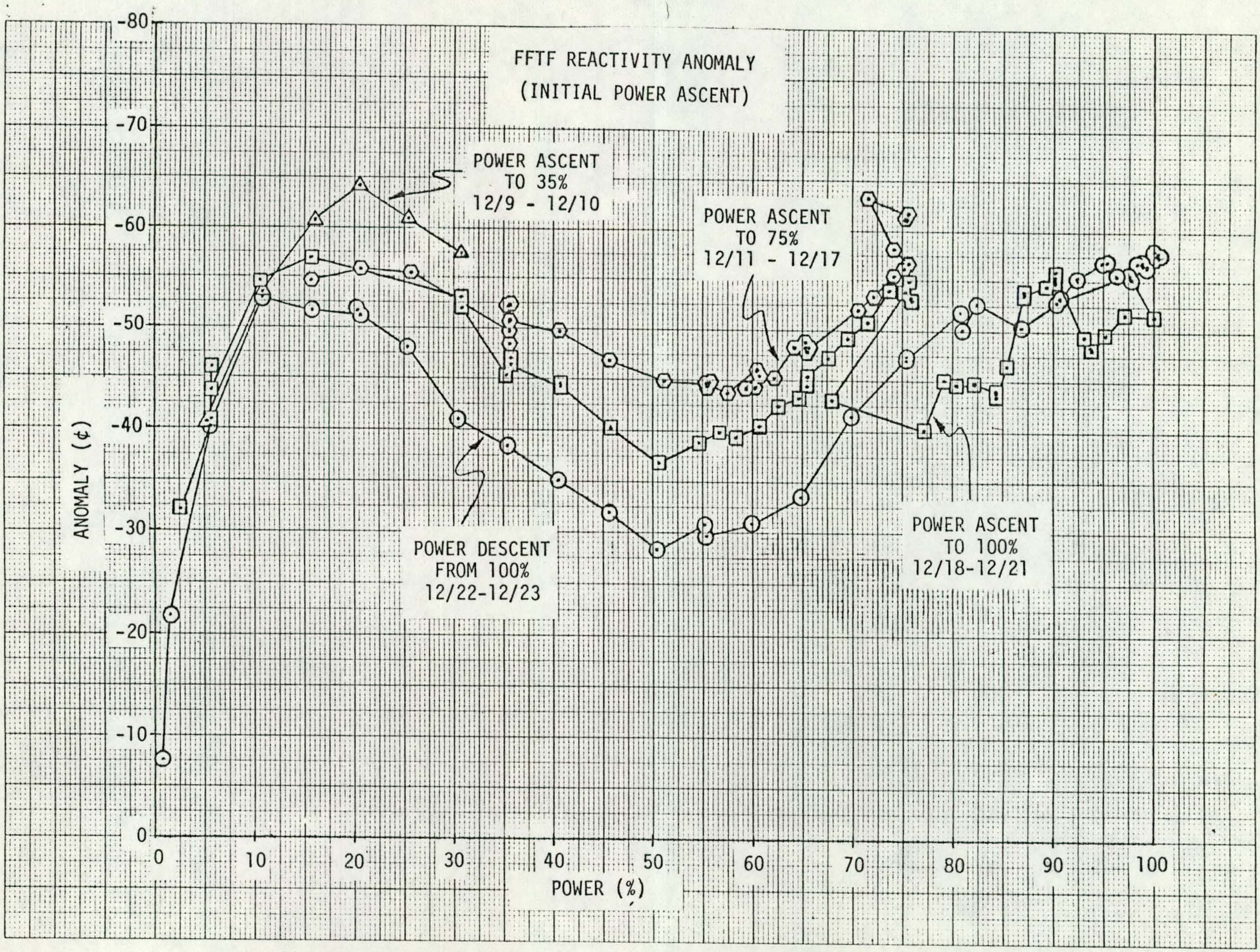


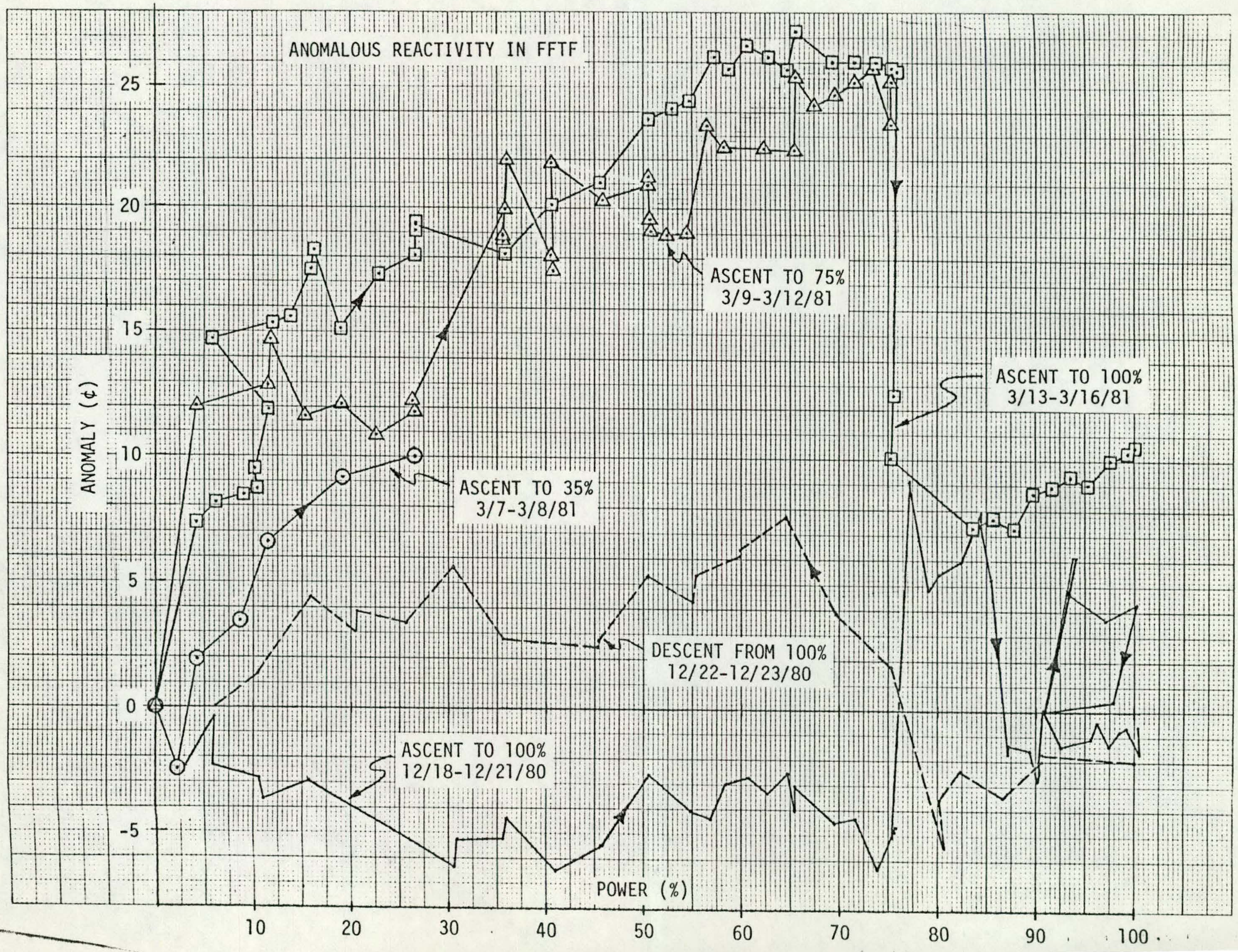


Predicted Reactivity Feedbacks in FFTF


POWER REACTIVITY DEFECT
500
400
300
200
100
0
REACTIVITY (¢)
TOTAL
MEASURED POWER DEFECT
PREDICTED POWER DEFECT PLUS
CONTROL ROD EXPANSION EFFECT
ISOTHERMAL TEMPERATURE
DEFECT AND FLOW DEFECT
CONSTANT
FLOW-75%
CONSTANT
POWER/FLOW
0
10
20
30
40
50
60
70
80
90
100
POWER (%)


FFTF REACTIVITY ANOMALY
(OPERATION PRIOR TO 75%)
12/9 - 12/10
11/25
12/4 - 12/6
11/26 - 11/29
ANOMALY (¢)
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
POWER (%)


FFTF REACTIVITY ANOMALY
(INITIAL POWER ASCENT)
POWER ASCENT
TO 35%
12/9 - 12/10
POWER ASCENT
TO 75%
12/11 - 12/17
POWER DESCENT
FROM 100%
12/22-12/23
POWER ASCENT
TO 100%
12/18-12/21
ANOMALY (¢)
POWER (%)
-80
-70
-60
-50
-40
-30
-20
-10
0
0
10
20
30
40
50
60
70
80
90
100


ANOMALOUS REACTIVITY IN FFTF
ANOMALY (¢)
25
20
15
10
5
0
-5
POWER (%)
10
20
30
40
50
60
70
80
90
100
ASCENT TO 75%
3/9-3/12/81
ASCENT TO 100%
3/13-3/16/81
ASCENT TO 35%
3/7-3/8/81
DESCENT FROM 100%
12/22-12/23/80
ASCENT TO 100%
12/18-12/21/80

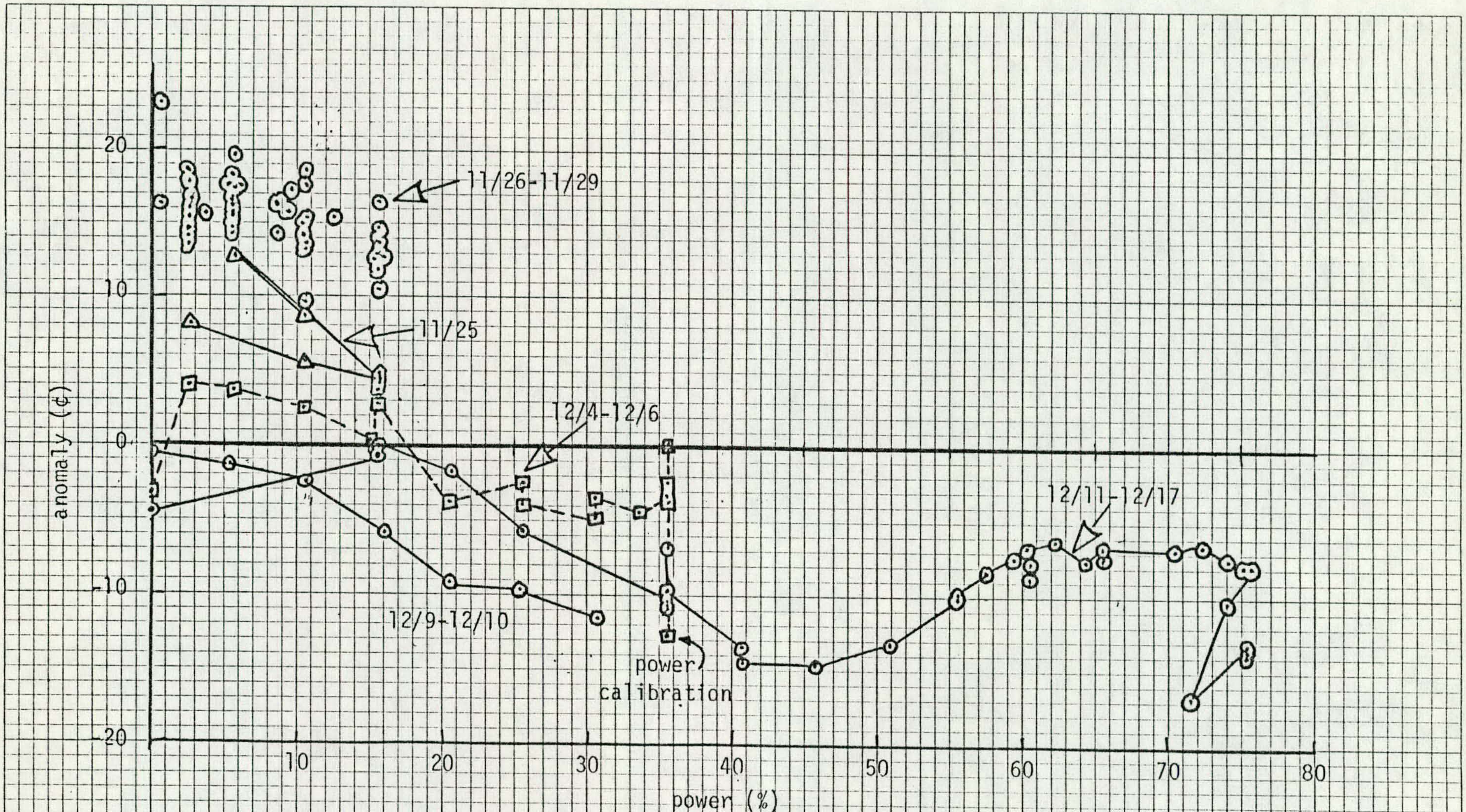
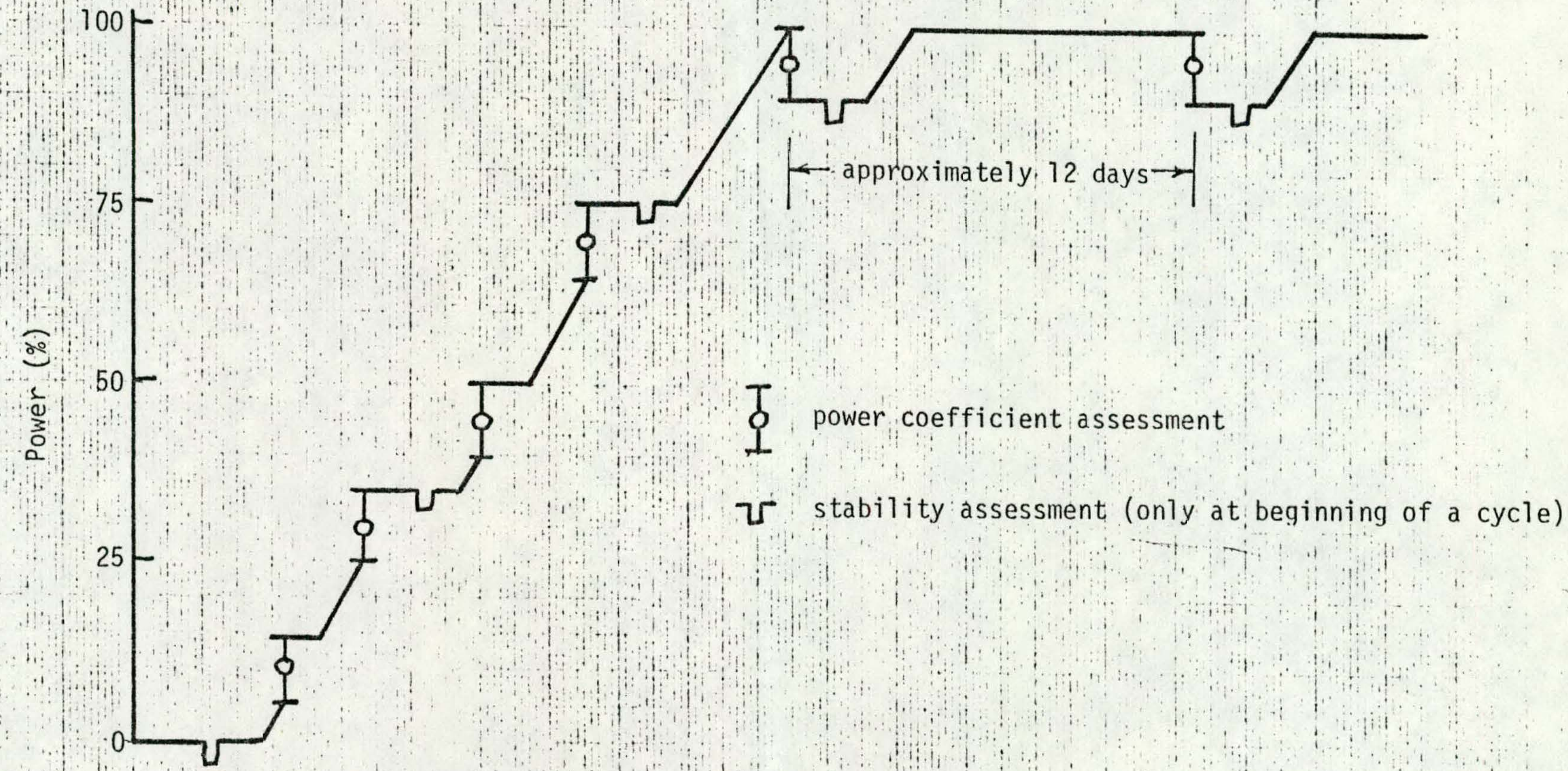


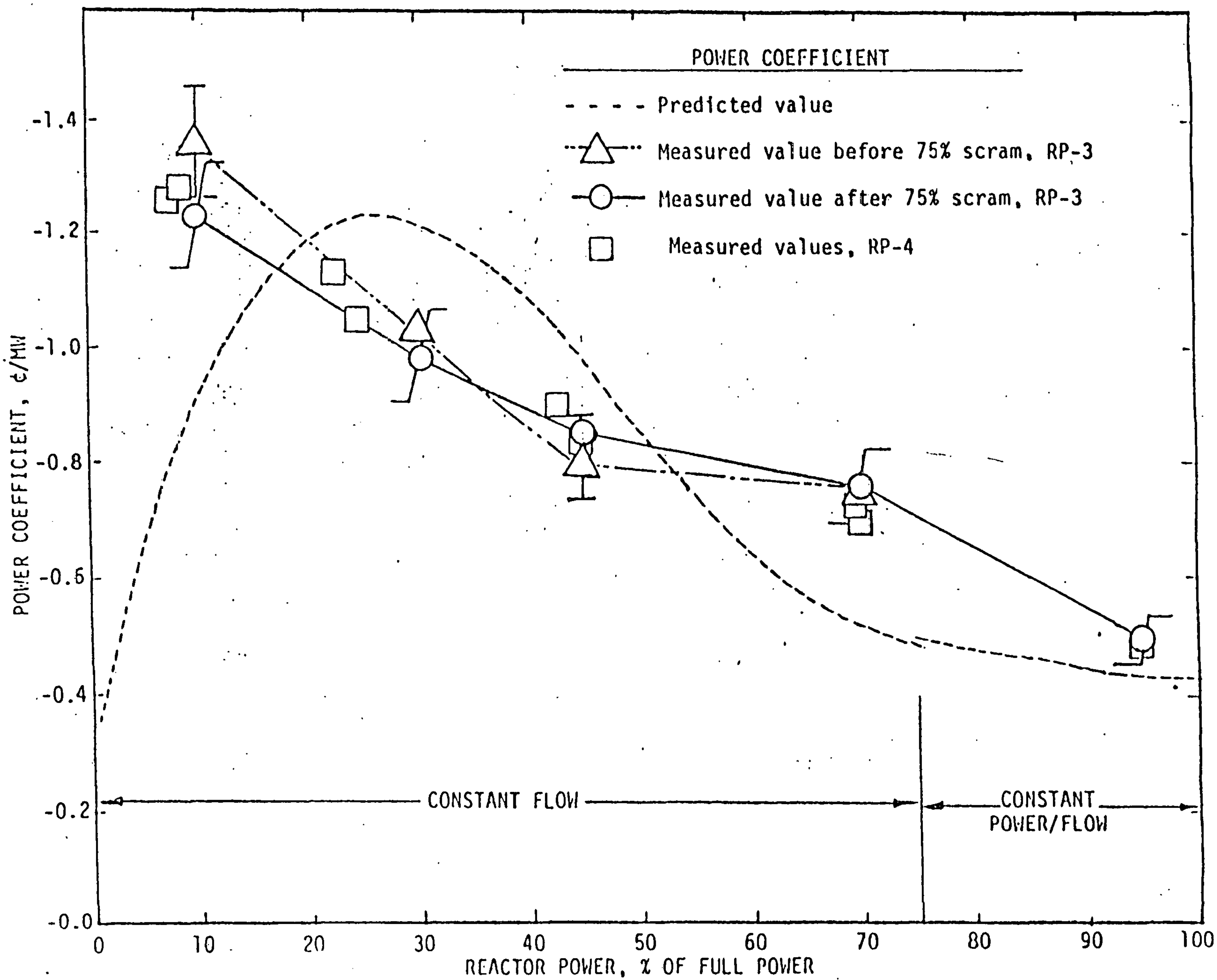
Figure 2. FFTF Reactivity Anomaly up to 12/17 Using Revised Algorithm.



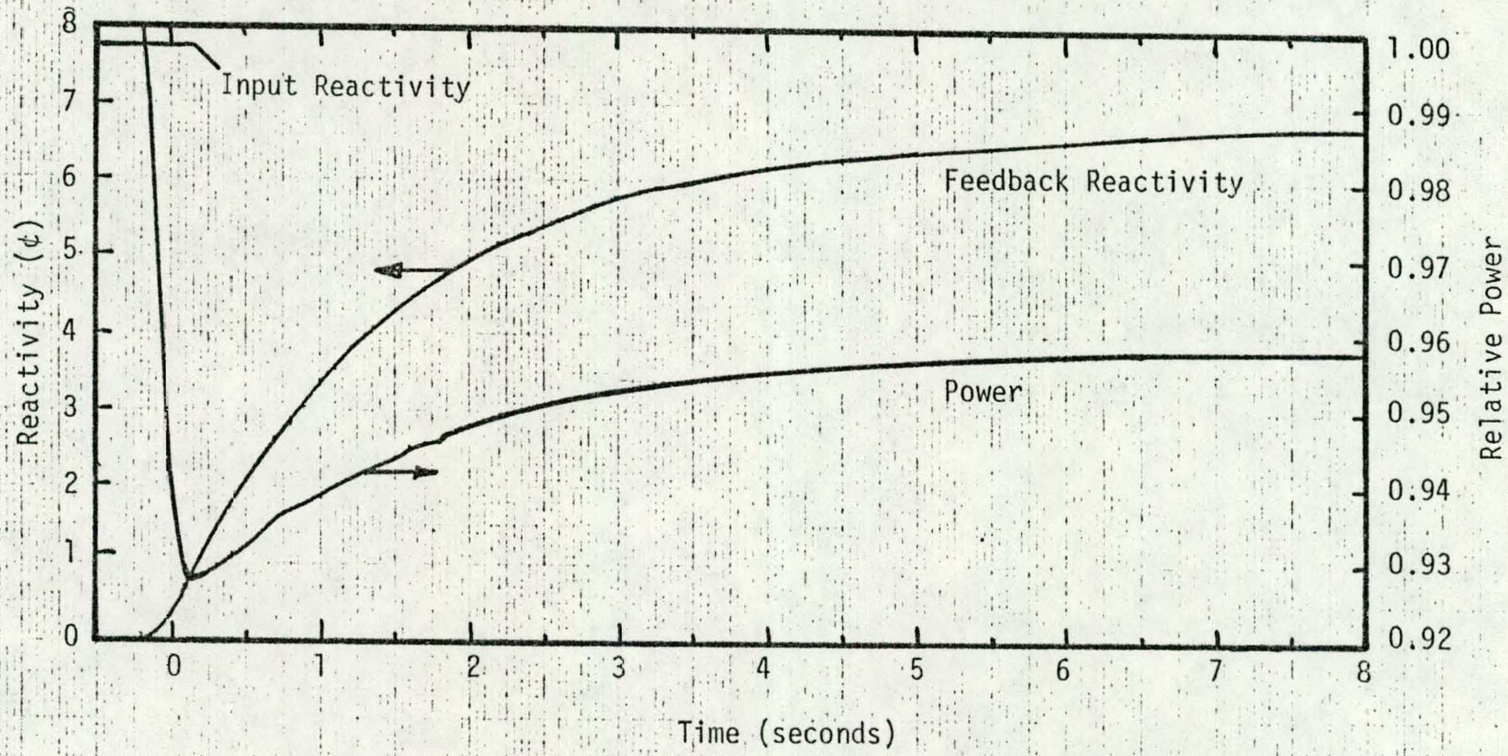
Stability Monitoring in FFTF

STABILITY AND REACTIVITY COEFFICIENT REQUIREMENTS

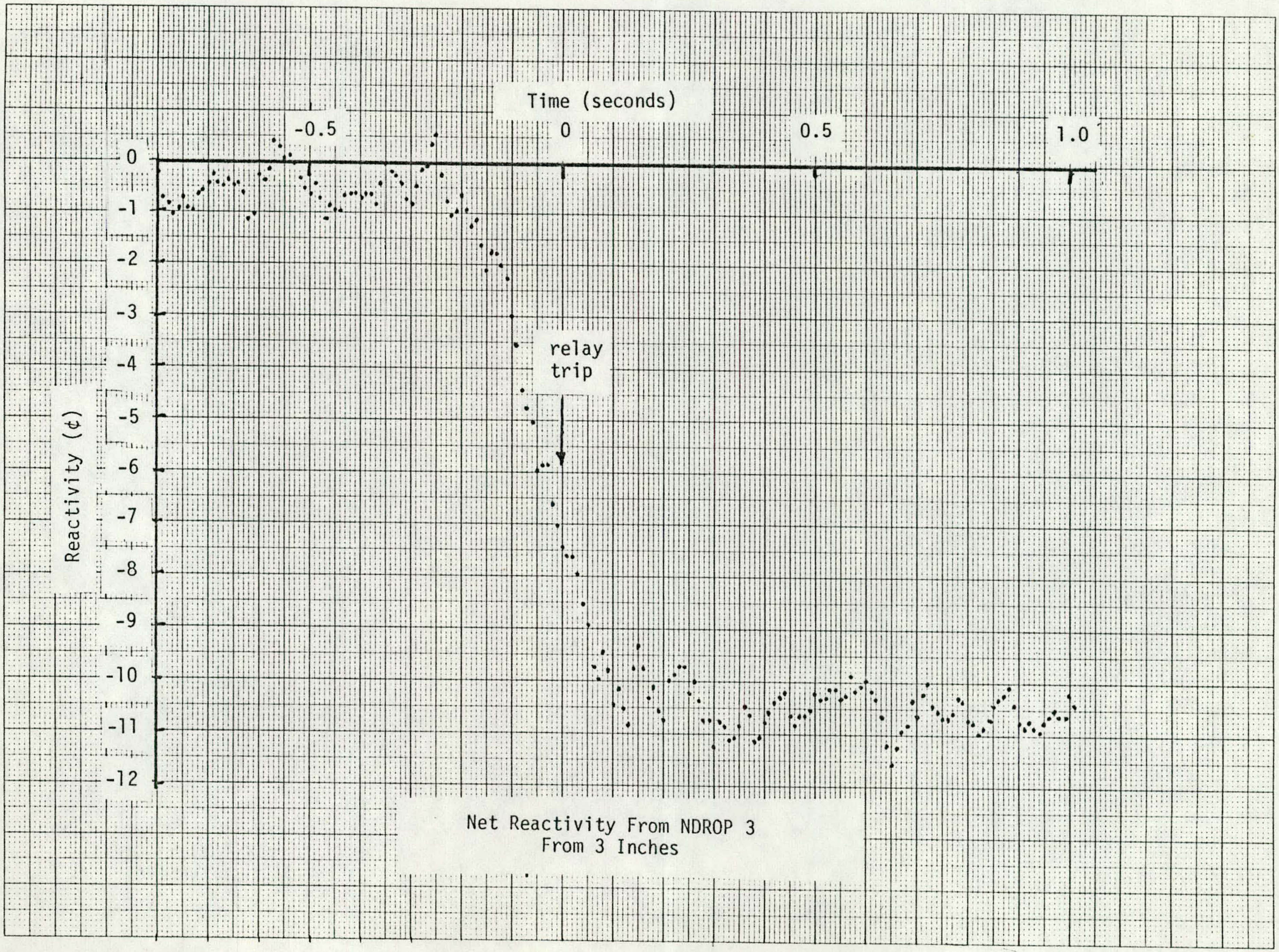
- VERIFY TECHNICAL SPECIFICATION LIMITS
- CHARACTERIZE ALTERNATE TECHNIQUES
- OBTAIN AN ACCURATE DATA BASE



POWER COEFFICIENT
Predicted value
Measured value before 75% scram, RP-3
Measured value after 75% scram, RP-3
Measured values, RP-4
POWER COEFFICIENT, ¢/MW
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
-0.0
0
10
20
30
40
50
60
70
80
90
100
REACTOR POWER, % OF FULL POWER
CONSTANT FLOW
CONSTANT POWER/FLOW



Power and Reactivity Following Rod Drop at 71.5% Power



Net Reactivity From NDROP 3
From 3 Inches

SUMMARY OF ROD DROP STABILITY MEASUREMENTS[1]

INITIAL POWER LEVEL (%)	STATIC POWER COEFF. (¢/MW)	INPUT REACT. (¢)	PHASE MARGIN (°)	INFERRED INPUT REACT. (¢)	INFERRED POWER COEFF. (¢/MW)	PROMPT[2] POWER COEFF. (¢/MW)
15	-1.35	-10.45	118.2 ± 0.3	-10.3 ± 0.1	-1.18 ± 0.04	-0.96 ± 0.02
35	-1.03	-10.45	109.4 ± 0.6	-10.0 ± 0.2	-0.99 ± 0.06	-0.80 ± 0.06
71.5	-0.76	- 7.77	102.1 ± 0.7	- 7.6 ± 0.2	-0.74 ± 0.04	-0.56 ± 0.04
35	-0.98	-10.16	108.6 ± 0.3	- 9.8 ± 0.2	-0.93 ± 0.04	-0.73 ± 0.03
91	-0.53[3]	- 5.46	105.2 ± 1.6	- 5.3 ± 0.2	-0.53	-0.40

(1) USING ROD WORTH INFERRED FROM MEASUREMENT

(2) FEEDBACKS WITH TIME CONSTANTS OF 2.0-5.0 SECONDS

(3) ESTIMATED

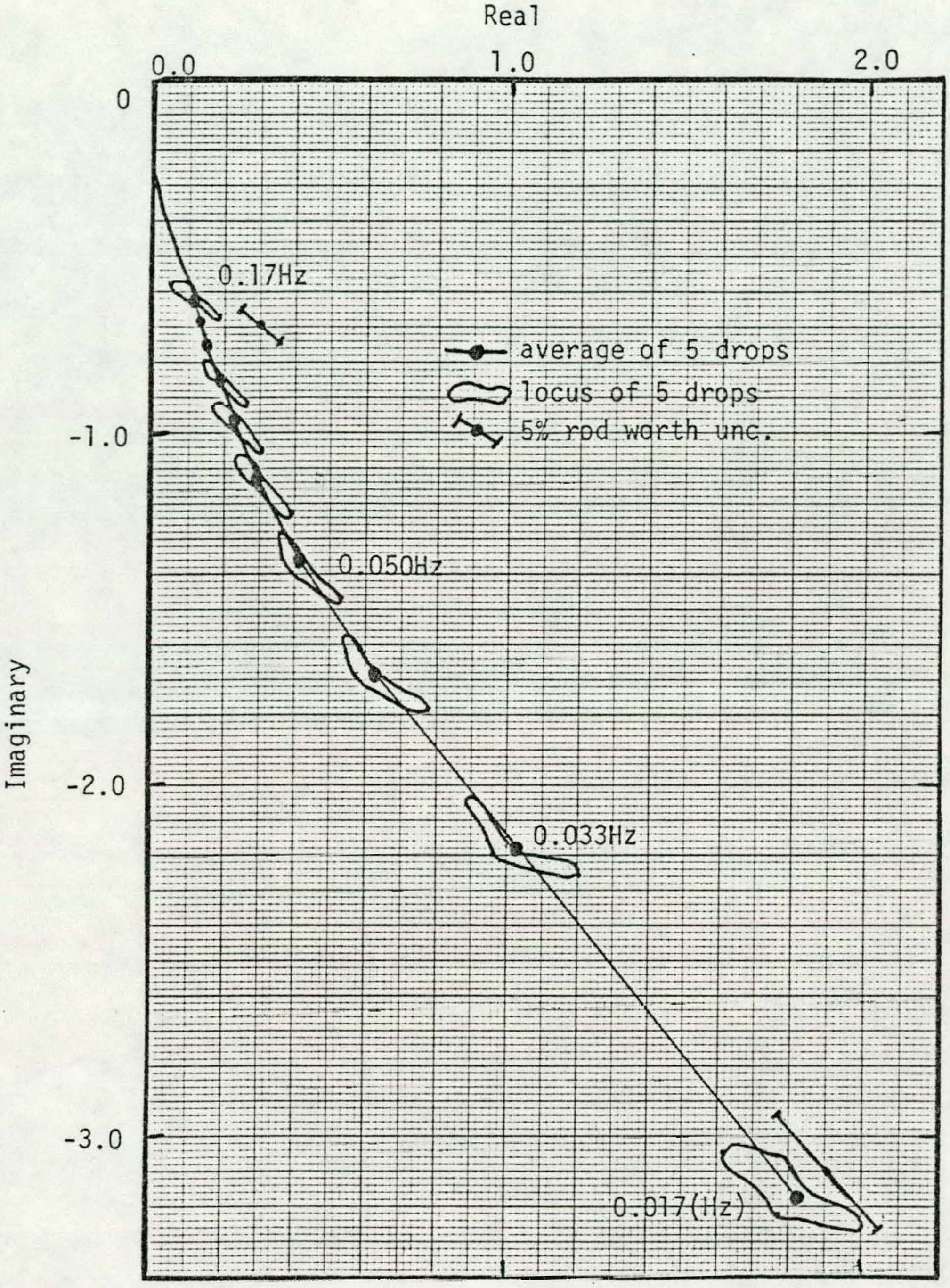
SUMMARY OF ROD DROP STABILITY MEASUREMENTS[1]

INITIAL POWER LEVEL (%)	STATIC POWER COEFF. (¢/MW)	INPUT REACT. (¢)	PHASE MARGIN (°)	INFERRED INPUT REACT. (¢)	INFERRED POWER COEFF. (¢/MW)	PROMPT[2] POWER COEFF. (¢/MW)
15	-1.35	-10.45	118.6 ± 1.5	-10.4 ± 0.1	-1.20 ± 0.02	-0.99 ± 0.07
35	-1.03	-10.45	110.5 ± 1.4	-10.4 ± 0.1	-1.03 ± 0.04	-0.84 ± 0.02
71.5	-0.76	- 7.77	103.2 ± 2.1	- 7.8 ± 0.2	-0.75 ± 0.05	-0.57 ± 0.03
35	-0.98	-10.16	109.3 ± 1.4	-10.1 ± 0.2	-0.95 ± 0.03	-0.75 ± 0.02
91	-0.53[3]	- 5.46	106.5 ± 2.1	- 5.5 ± 0.2	-0.54	-0.42

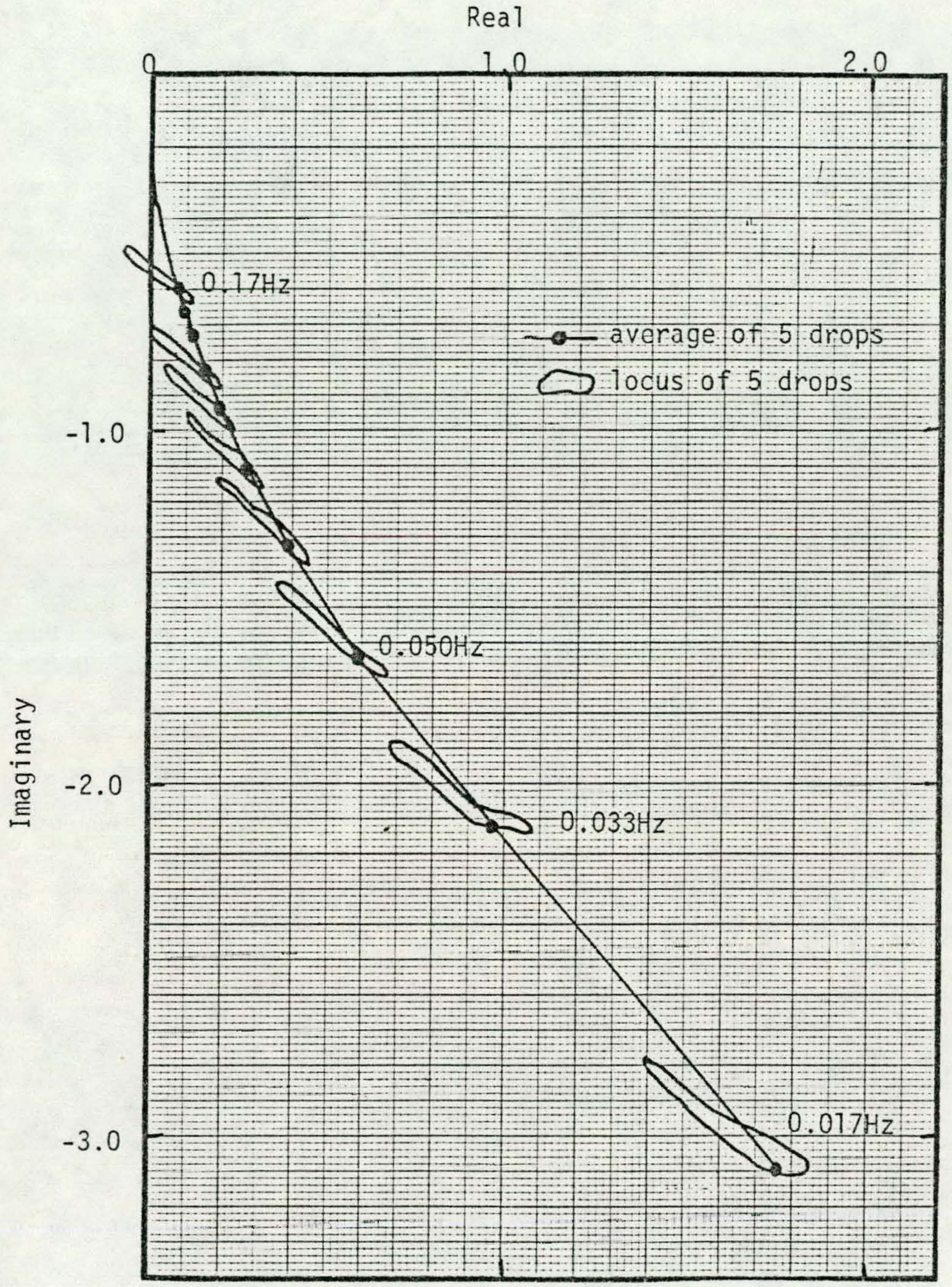
(1) USING ROD WORTH MEASURED AT ZERO POWER

(2) FEEDBACKS WITH TIME CONSTANTS OF 2.0-5.0 SECONDS

(3) ESTIMATED



Nyquist Diagram for Drop at 75% Power
Using Measured Rod Worth



Nyquist Diagram for Drop at 75% Power
Using Inferred Rod Worth

FUTURE ACTIVITIES

CONTINUOUSLY COLLECT REACTIVITY DATA

- o REACTIVITY ANOMALY
- o POWER COEFFICIENT
- o STABILITY ASSESSMENT
- o NEUTRON SOURCE ASSESSMENT
- o RELOADING REACTIVITY EFFECT
- o ROD AND ROD BANK WORTHS

SPECIAL REACTIVITY MEASUREMENTS (DATA BASE)

- o FLOW COEFFICIENT
- o TEMPERATURE COEFFICIENT
- o DIFFERENTIAL ROD WORTH
- o MULTIFREQUENCY BINARY SEQUENCE (MFBS)
- o STABILITY TECHNIQUE COMPARISON
  - ROD DROP
  - ROD RUN-IN
  - MFBS