UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 2, 1997

MEMORANDUM TO: David B. Matthews, Chief
Generic Issues and Environmental
Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

FROM: Claudia M. Craig, Senior Project Manager Claudia M. Craig
Generic Issues and Environmental
Projects Branch
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

SUBJECT: SUMMARY OF MEETING WITH WESTINGHOUSE TO DISCUSS FUEL PERFORMANCE ISSUES

The subject meeting was held at the Nuclear Regulatory Commission (NRC) offices in Rockville, Maryland on June 24, 1997, between representatives of Westinghouse and the NRC staff. The NRR staff requested Westinghouse to discuss recent fuel performance issues. The presentation was divided into three portions: fuel performance summary, fuel performance at Seabrook, and fuel improvement program summary. Attachment 1 is a list of meeting participants. Most of the meeting was closed to the public due to the proprietary nature of the information being discussed; however, a non-proprietary version of the presentation material was provided by Westinghouse. By separate letter, Westinghouse provided both proprietary and non-proprietary versions of the material presented at the meeting. Attachment 2 is a copy of the non-proprietary version of the presentation material.

In the non-proprietary portion of the meeting, Westinghouse summarized the fuel performance for the Vantage 5H fuel and for fuel using Zirlo. Due to confusion in the different types of Westinghouse fuel referenced by both licensees and Westinghouse, the staff requested Westinghouse provide a list of the different fuel types and the various names that may be referenced such that the staff is better able to understand the nomenclature.

In the proprietary portion of the meeting, Westinghouse discussed in detail the leakage mechanisms that have been identified, the number of incidents that have occurred, and the corrective actions taken to correct the problem. Westinghouse concluded that fuel reliability is improving even though fuel is being pushed to higher burnups and longer cycles. No materials impacts of Zirlo have been observed, and it appears the corrective actions taken have been effective.

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Westinghouse also discussed the results of their efforts on the failed fuel rods at the Seabrook plant. Westinghouse described the results of their inspections, their preliminary assessment, and their action plan to determine the root cause of the failure. The preliminary assessment is that the

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failures do not appear to be attributable to mechanical damage, the manufacturing records do not show anything of note, and the failed rods were high power rods adjacent to thimble tubes. Westinghouse will continue their evaluations and outlined their schedule of activities, including an update to the NRC staff in September 1997.

Westinghouse concluded the meeting by discussing their fuel improvement programs that involve a variety of activities, including testing, inspection, and design work.

The participants concluded that the meeting was very useful and discussed the possibility of conducting future meetings on the topic to keep apprised of activities.

Attachments: As stated

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WESTINGHOUSE / NRC MEETING

FUEL PERFORMANCE ISSUE

JUNE 24, 1997

MEETING PARTICIPANTS

NAME	ORGANIZATION
Claudia Craig	NRC/NRR/PGEB
Muffet Chatterton	NRC/NRR/SRXB
Shih-Liang Wu	NRC/NRR/SRXB
Larry Kopp	NRC/NRR/SRXB
H.L. Ornstein	NRC/AEOD
Paul Gunter	NIRS
Lynn Connor	DSA
Larry Phillips	NRC/NRR/SRXB
Ron Knott	Westinghouse/CNFD
Sumit Ray	Westinghouse/CNFD
George P. Sabol	Westinghouse/CNFD
David J. Colburn	Westinghouse/CNFD
Tony Attard	NRC/NRR/SRXB
Harold H. Scott	NRC/RES/DST

ATTACHMENT 1

Fuel Performance Meeting with USNRC

June 24, 1997

Operating Conditions Continue to Push Fuel Duty

- High energy cores
  - Longer cycles
  - Higher burnups
  - Low leakage loading patterns
  - Aggressive coolant chemistry strategies
- Upratings
  - Higher power
  - Higher temperatures

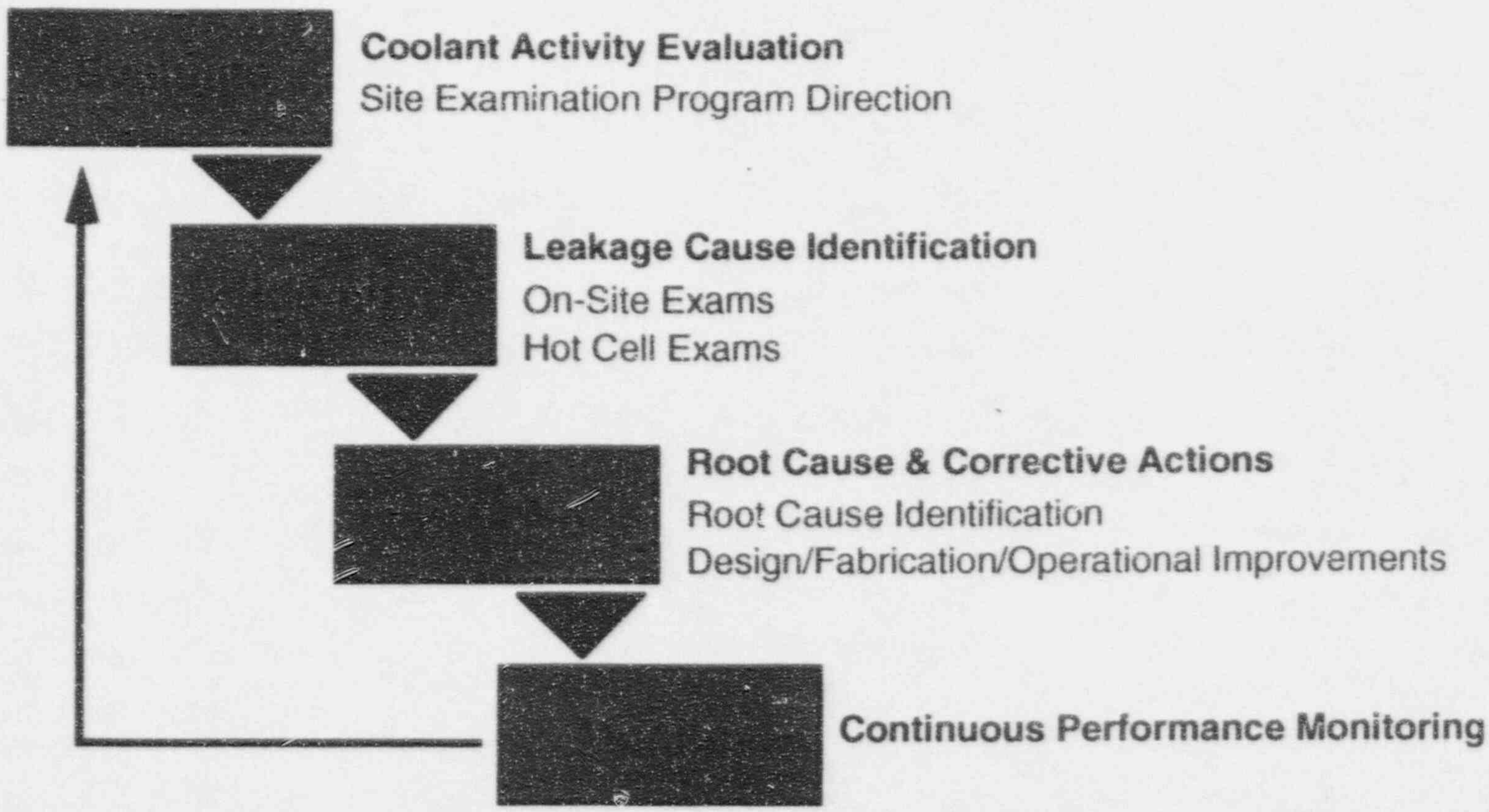
- Fuel performance
  - Reliability
  - Operability

Westinghouse Fuel Reliability

Percent of Plants

Fuel reliability improving while fuel duty continues to become more demanding

Improved Fuel Performance Process



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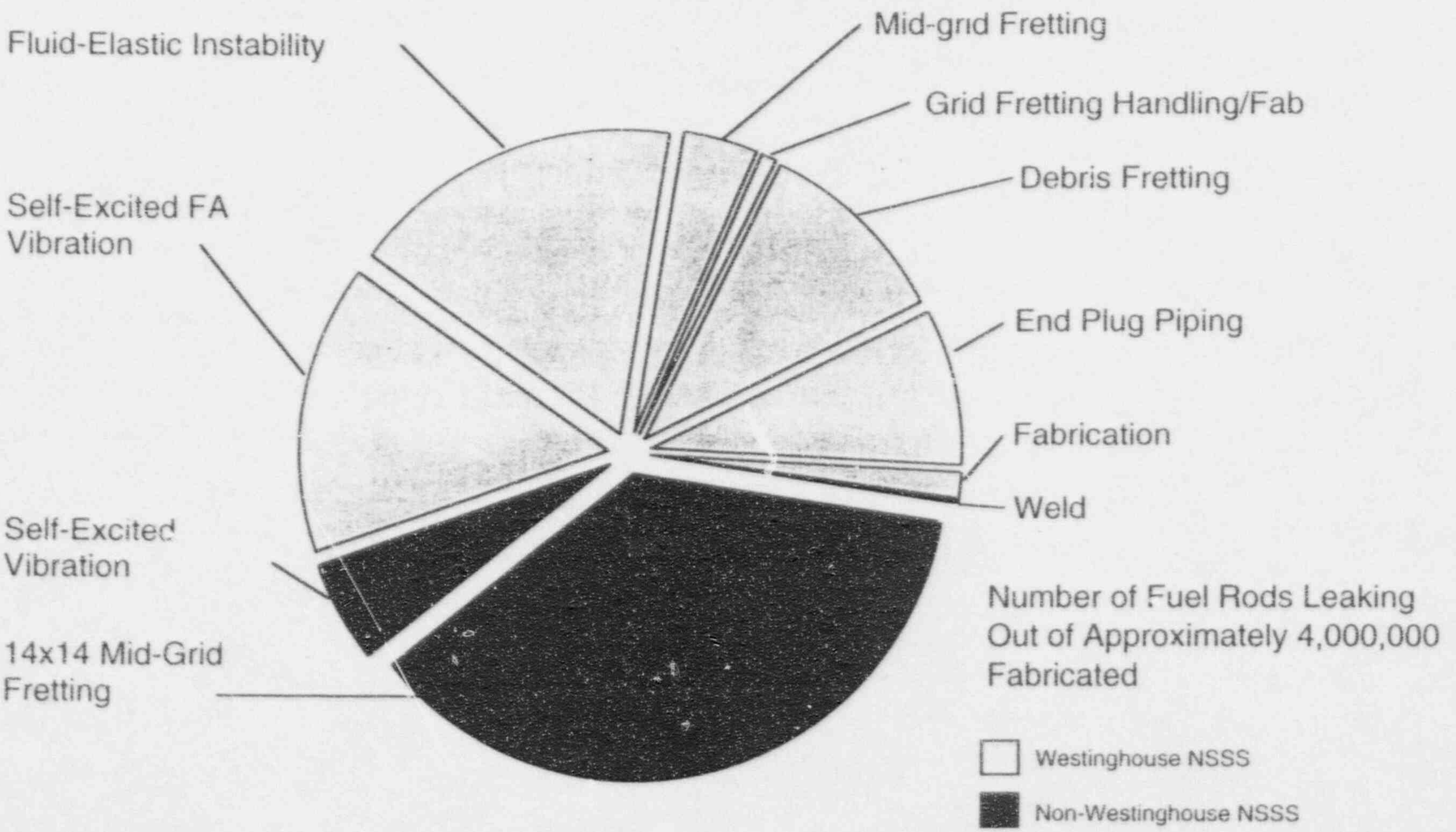
Leakage Mechanisms
Fuel Fabricated 1988 and Later



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Fuel Reliability Summary

- Focus on fuel fabricated in 1988 and later
- Greater than 4,000,000 fuel rods fabricated over this period
- A total of (<) fuel rods identified as leaking (W NSSS)
  - 15% debris fretting related
  - 55% grid-rod fretting related
    - 23% self-excited fuel assembly vibration
  - 12% end plug piping
  - 2% "Hydride Only"/weld related

Actions Taken/CE NSSS

Key considerations

- Several potential sources of multiple-span excitation
  - Plant base motion
  - Cross flows (unidentified)
  - Combinations

Corrective actions

- Alternating spring/dimple axially along fuel rod
- Softer grid spring (lower k)
- More open outer strap

Benefit of Corrective Actions Shown in Testing

Corrective actions provide significant benefit for grid-rod fretting

Status

- One region of fuel with corrective actions currently in core
- Examination of revised design planned for upcoming outage
- Next cycle will have 2 regions with corrective actions plus fuel from SFP

Actions Taken/Ⓦ NSSS

Fluid-elastic instability

- Observed: 2 plants
- Actions: Shortened bottom span
- Status:
  - In fuel with protective grid
  - First plant: 2 regions
Operating defect-free, past time when defects were previously observed
  - Second plant: 1 region

Corrective action has addressed mechanism

Design Change to Eliminate Fluid-Elastic Instability

Actions Taken - Debris Fretting

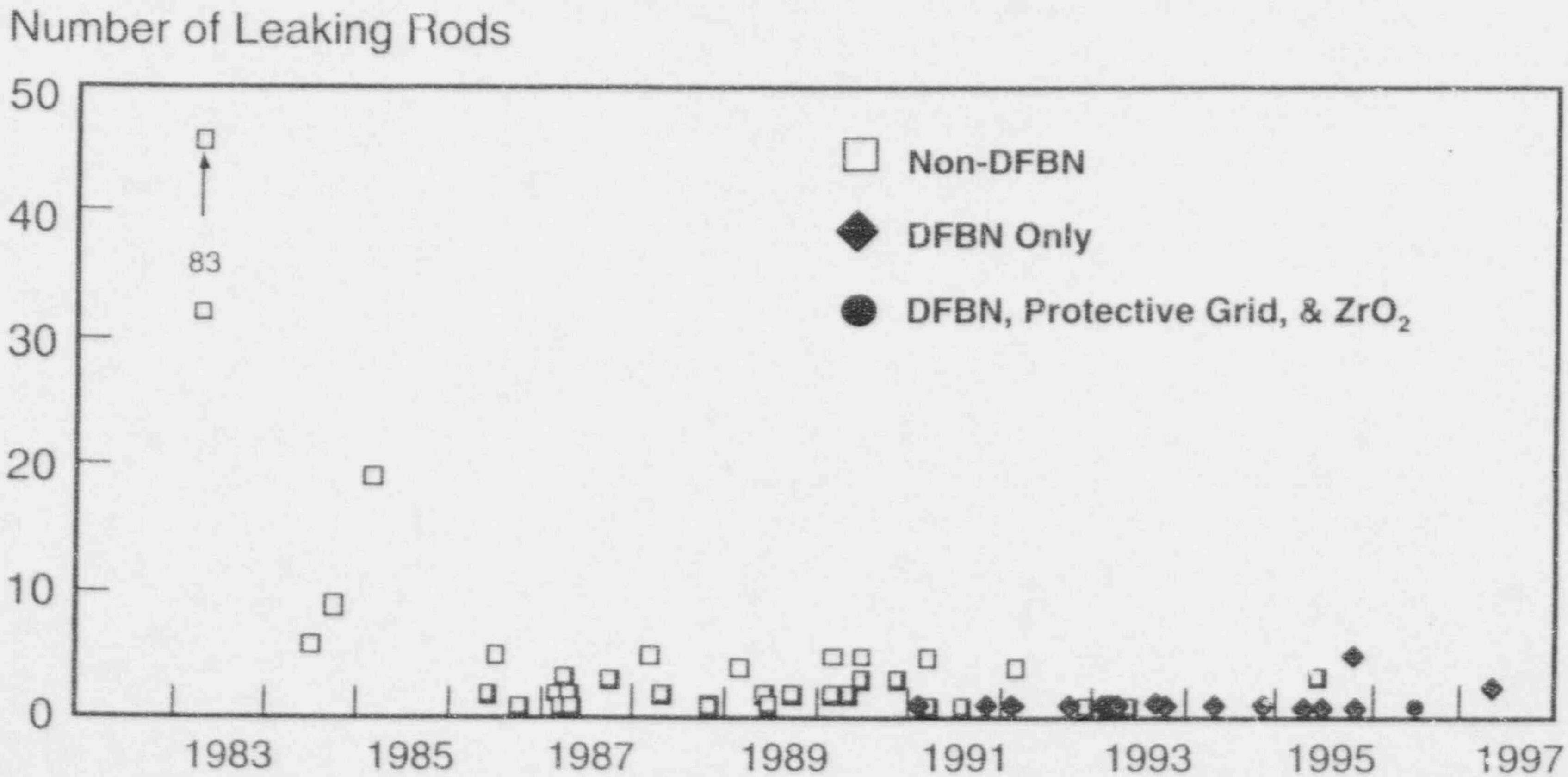
- Actions: DFBN, protective bottom grid, ZrO_2 coating
- Status: DFBN – Introduced 1988;

  Protective Grid – Introduced 1993;

  ZrO_2 Coating – Introduced 1993;

  Features plus FME practices have been beneficial

Debris-Induced Fretting Defects in Westinghouse-Fueled PWRs (1982-1997)



Mitigating features + FME practices have addressed mechanism

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Actions Taken - Fabrication/Weld

- Observed: plants
- Actions: Improvements to reduce contamination potential

  Weld equipment upgrades

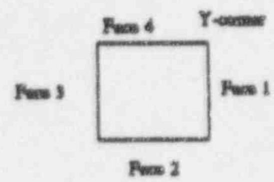
  Grooved end plug
- Status: Ongoing

Self-excited fuel assembly vibration (17x17 VANTAGE5H)

- Observed: 2 plants (+ LTA assemblies in non-Ⓦ plant)
  Observed in 1993
- Root Cause: Self-excited fuel assembly vibration due to non-symmetric vane pattern
- Actions: Alternate vaned grid rotation
  Modified grid design (MV5H)

Plant A

Cycle 8

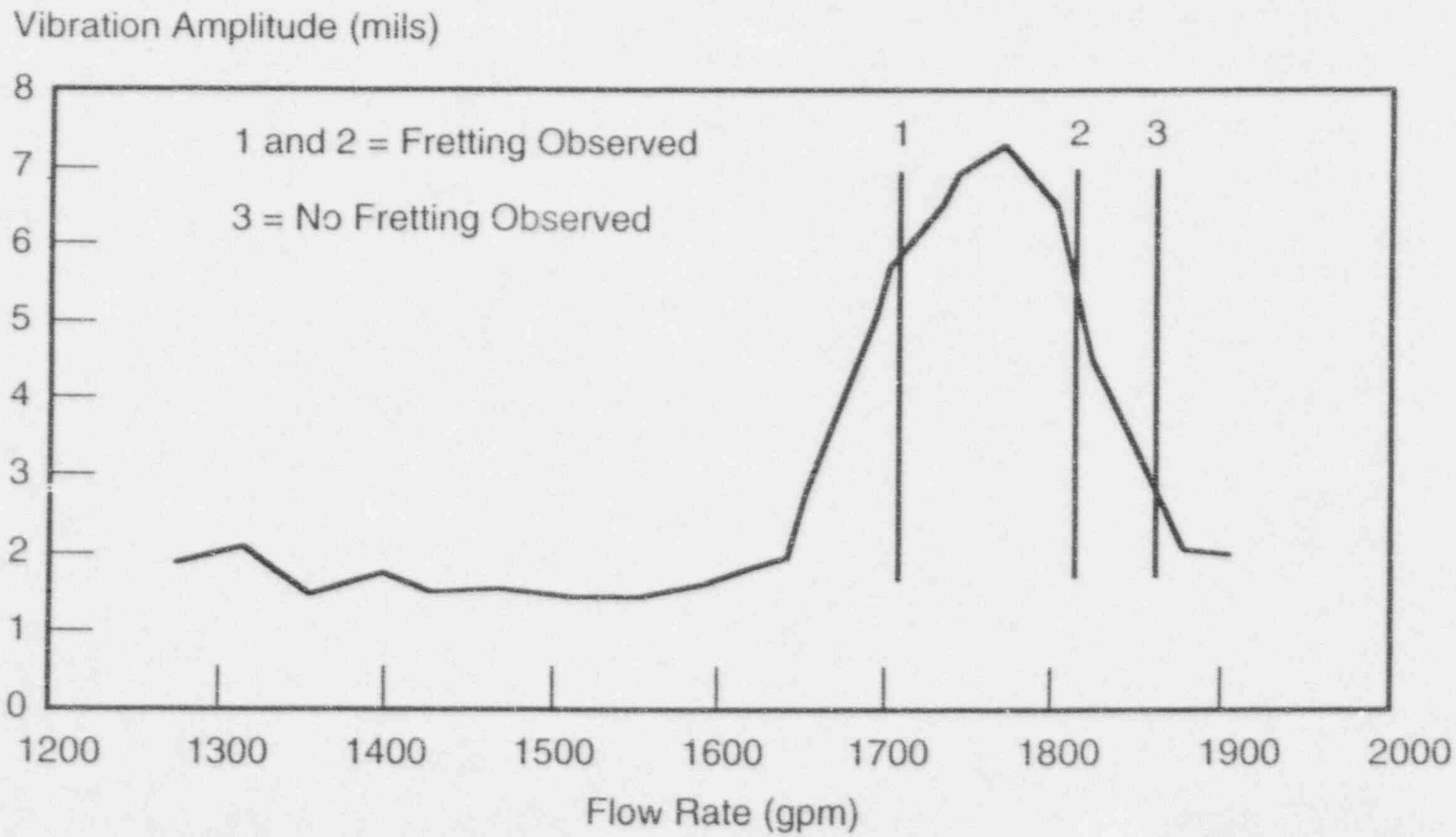


Plant B

Cycle 9

17x17 VANTAGE 5H Experience

17x17 Vantage 5H Fuel Assembly Vibration Without Corrective Action

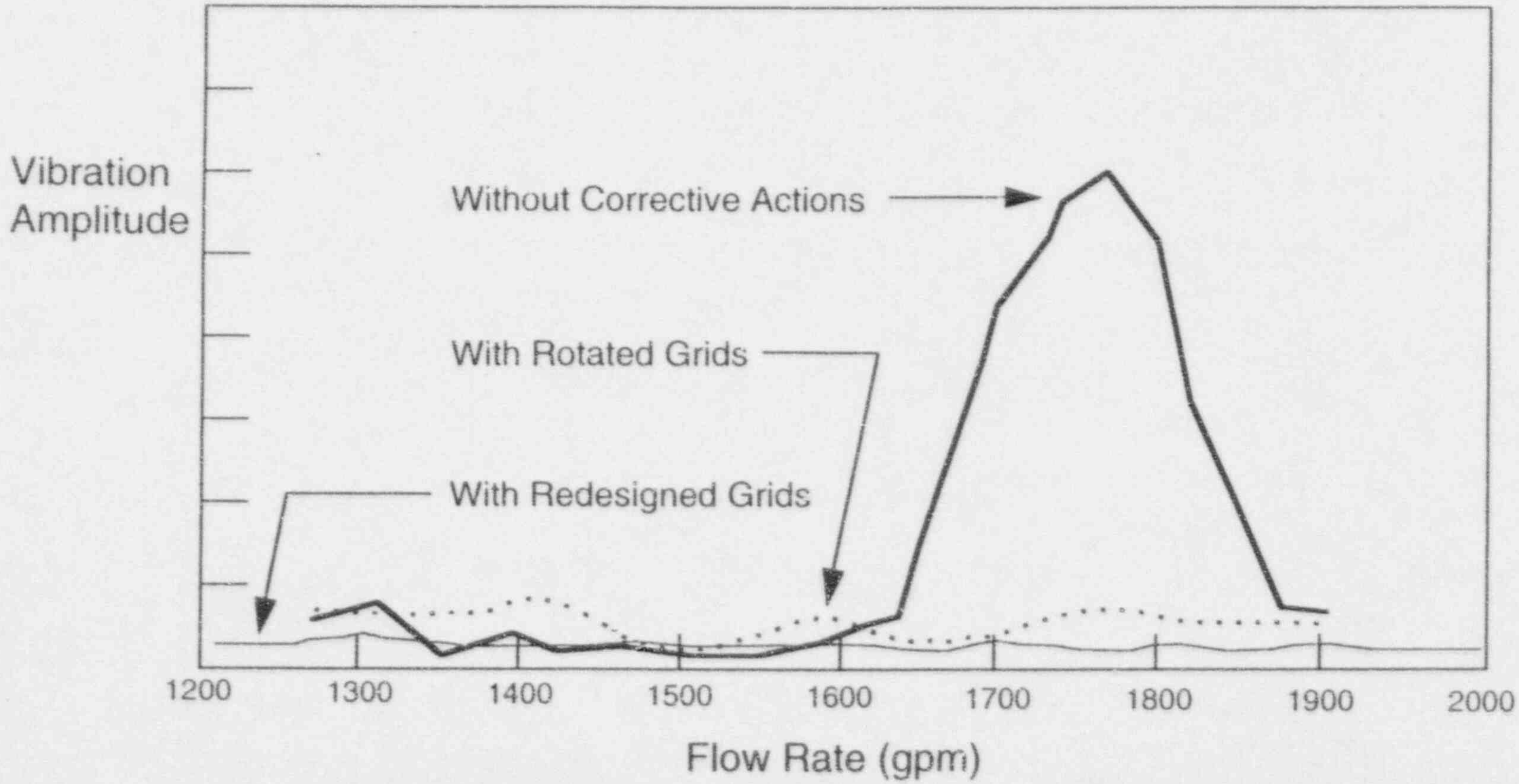


- **Mechanism active in narrow flow range**
- **Plants outside flow range have not observed mechanism**

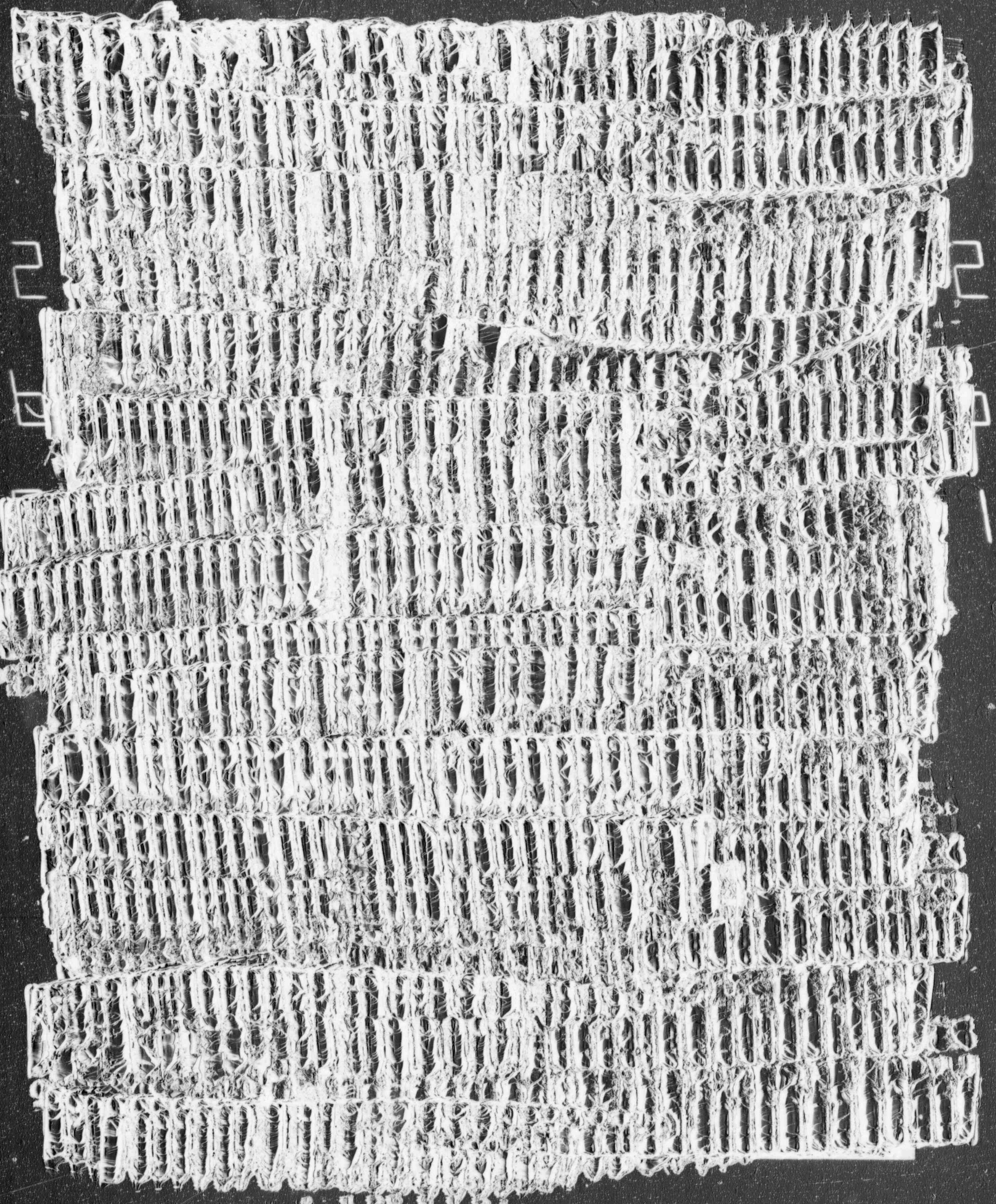
Frequency (Hertz)

17x17 V5H (Non-IFM) Fuel Assembly
Vibrational Frequencies and Mode Shapes
(Finite Element Modal Results)

17x17 VANTAGE 5H Fuel Assembly Vibration With and Without Corrective Actions



- **Corrective actions eliminate vibration**
- **All other Ⓦ designs do not show mechanism in flow test**



Self-excited fuel assembly vibration (17x17 VANTAGE5H)

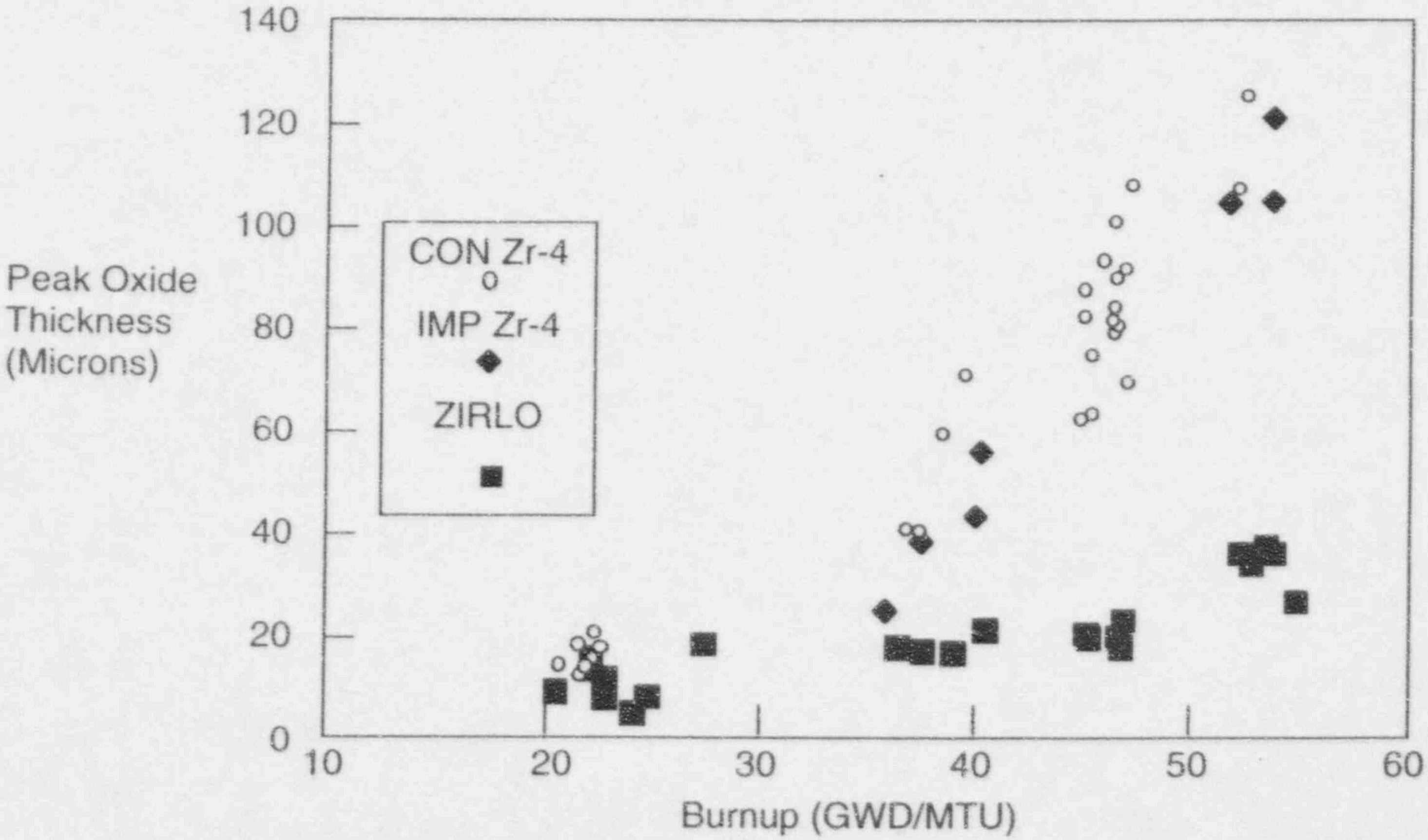
- Status: Grid rotation since 1993

  No mid-grid fretting in fuel with rotated grids

  New LTAs operating defect-free

Conclusion: Corrective actions have addressed mechanism

ZIRLO™ Provides Increased Margin to Cladding Corrosion Limits



- **Additional corrosion margin needed for high burnup**
- **Zirlo provides needed margin**

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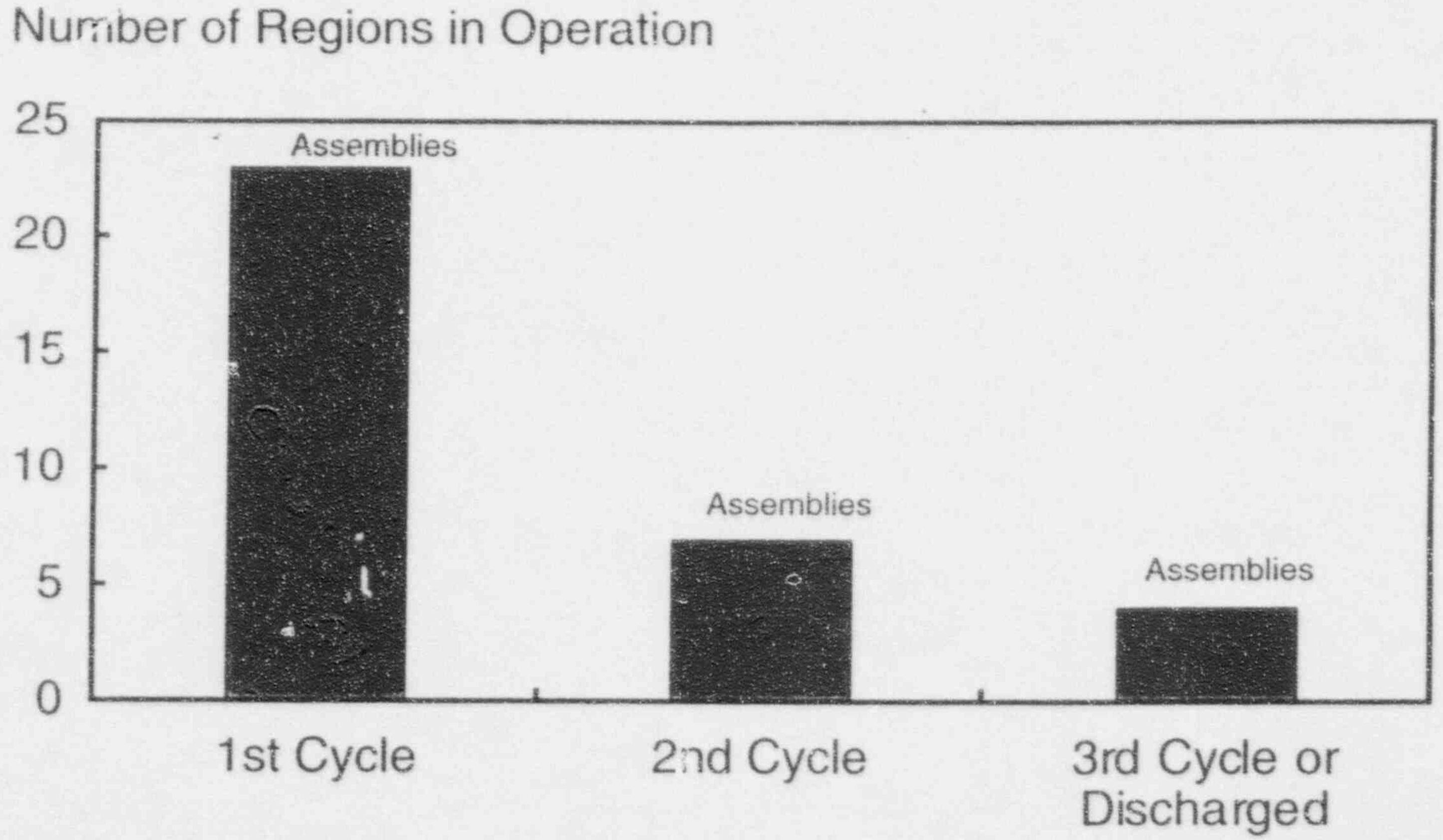
ZIRLO Implemented in Commercial Quantities

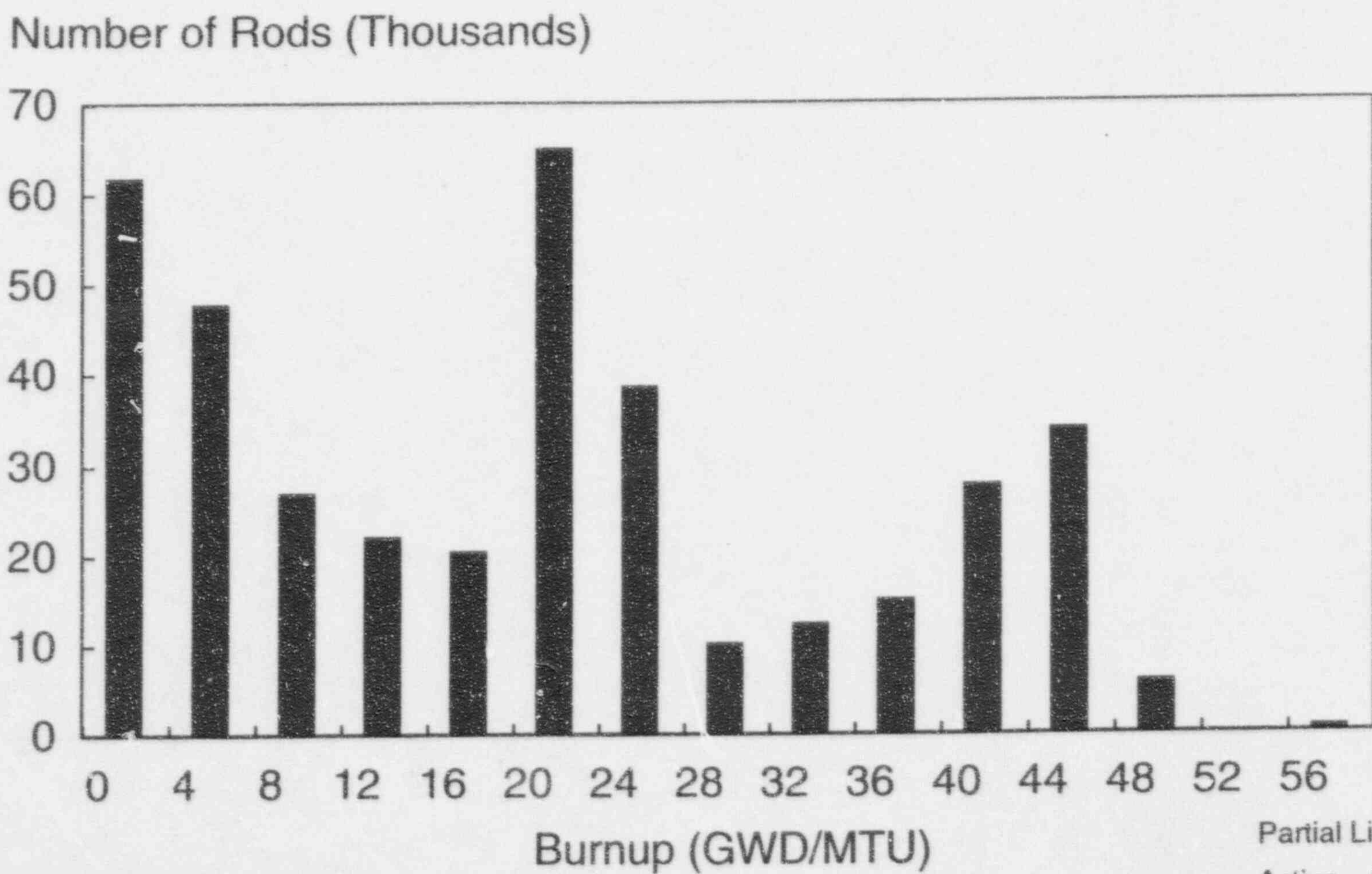
- Significant experience over two decades
  - Test reactor
  - LTAs
  - Commercial regions
- Widely accepted
  - Currently being used in 24 plants
  - Three quarters of 1997 Ⓦ production will be ZIRLO
- Also being used in several other countries

ZIRLO Achieving High Burnup



As of 3/31/97

Burnup Experience of Zirlo Fuel as of 3/31/97



Partial Listing
Active + Discharged

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Zirlo Leaking Fuel Rods

No Zirlo Related Leakage Mechanisms Identified

Zirlo Experience
Conclusion

Substantial Zirlo experience

- Up to ~ 60 GWD/MTU
- 75% of current production is Zirlo

No materials impacts of Zirlo observed

- Leaking rods limited: mostly debris related
- Significant experience above burnup levels of Seabrook fuel (100,000 rods)
- Broken rods also observed on Zr-4 rods
  - Power history is key parameter

IFBA Performance

Observed leakage mechanisms not IFBA related

- Root cause mostly either mechanical or fabrication related
- "Hydride Only" rods do not have definitive cause

Significant amount of IFBA operating experience

- 800,000 rods fabricated through 1996
- No IFBA related leakage cause found

Conclusion: IFBA performance excellent

Effectiveness of Corrective Actions In Westinghouse NSSS

Number of Fuel Rods Identified as Leakers*

Westinghouse Fuel Performance Summary

- Fuel reliability improving while fuel duty is becoming more demanding
- CNFD objective is zero defect performance
  - Identify leakage causes
  - Define and implement corrective actions
- No Zirlo related leakage causes identified
- Root cause and corrective actions identified and implemented for observed leakage causes
- Operating experience indicates corrective actions effective
  - No fretting defects in V5H rotated grid assemblies
  - MV5H LTAs to be inserted in core in fall 1997
- Actions continue to address current issues

Westinghouse Fuel Performance Seabrook Cycle 5

David J. Colburn

NRC Update

June 24, 1997

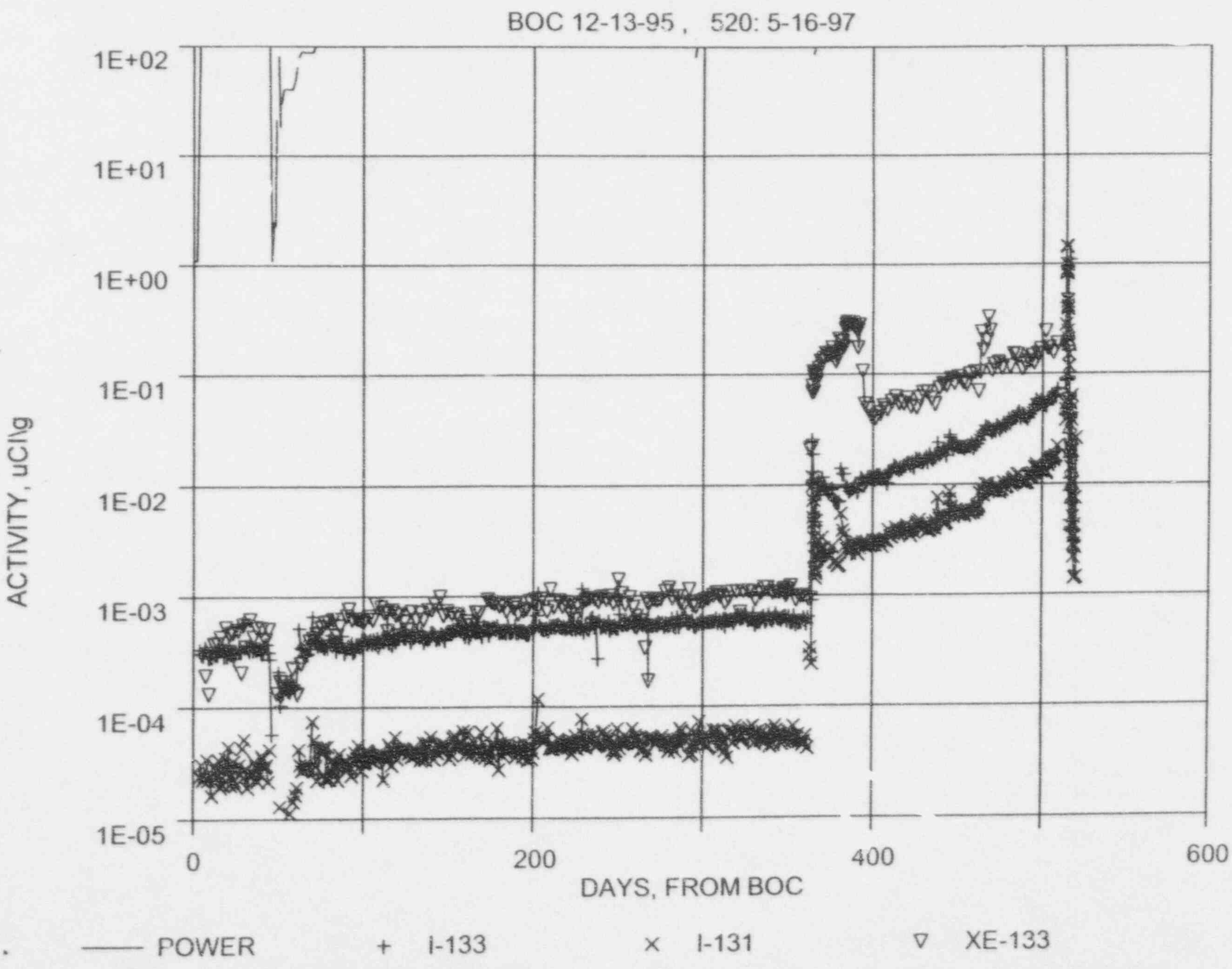
Outline

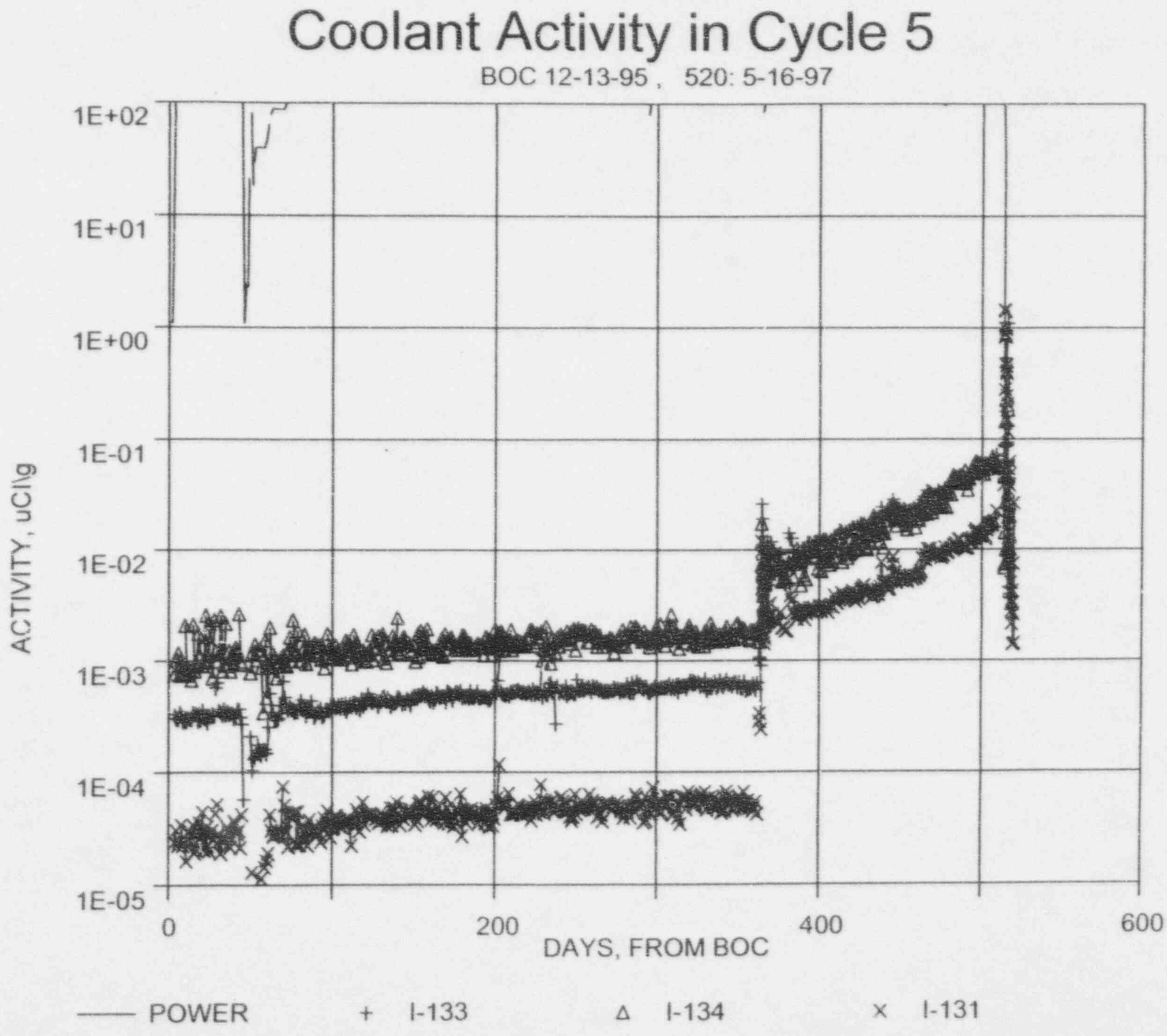
- Coolant Activity in Cycle 5
- Fuel Inspection Results
- Assembly Reconstitution
- Failed Fuel Rod Inspections
- Sound Fuel Rod Inspections
- Preliminary Assessment
- Action Plan
- Schedule

Cycle 5 Coolant Activity

- No evidence of significant coolant activity until 362 days into the cycle
- Sudden step change indicating open defects
- Xe peaks early during the event show at least two distinct failure events
- Continuous increase indicates fuel degradation worsening

Coolant Activity in Cycle 5




Coolant Activity in Cycle 5
BOC 12-13-95 , 520: 5-16-97
1E+02
1E+01
1E+00
1E-01
1E-02
1E-03
1E-04
1E-05
ACTIVITY, uCI\g
0
200
400
600
DAYS, FROM BOC
POWER
I-133
I-134
I-131

Fuel Inspection Results

- All 193 assemblies leak checked by In-Mast Sipping
- Four assemblies from “G” region identified as leaking
- Ultrasonic Inspection on Four assemblies identified 1 leaking rod in 3 assemblies and 2 leaking rods in the fourth

Assembly Reconstitution

- First 2 rods broke near grid 4 during retrieval attempts on first assembly
- Next 2 assemblies were successfully repaired
- One additional rod broke during removal from fourth assembly

Failed Fuel Rod Inspections

- Failed rods showed:
  - Circumferential cracks or breakage near grid 4 (approximately 63-75 inches from the bottom of the fuel rod)
  - Axial cracks in upper spans between grid 6 and 7 (93 inches)
  - light crud in bottom half with increasing thickness from grid 5 to grid 7
  - No evidence of external damage from fretting or debris

Sound Rod Inspections

- Ten good rods were removed from 3 of the 4 effected assemblies for inspection
  - 8 IFBA rods and 2 Non-IFBA high power rods with similar locations of failed rods
  - Crud deposition similar to that of failed rods
  - No evidence of cracks or fretting
  - Rods were replaced with stainless steel

Preliminary Assessment

- Failures do not appear attributable to mechanical damage such as grid-rod fretting or debris fretting
- Manufacturing records do not show commonality of note
- Failed rods were high power rods in lead assemblies containing IFBA, adjacent to thimble tubes

Preliminary Assessment (con't)

- Characteristics of IFBA
  - Commonly used (12/80 128 IFBA)
  - Normaly have IFBA rods adjacent to thimbles
  - No significant difference between IFBA designs in assembly peaking
  - 128 IFBA assemblies were designed to operate at higher power in Cycle 5 (loading pattern effect)

SEABROOK CYCLE 5
IFBA ASSEMBLY CONFIGURATIONS

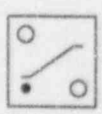
LEGEND

● IFBA Rod

□ Fuel Rod

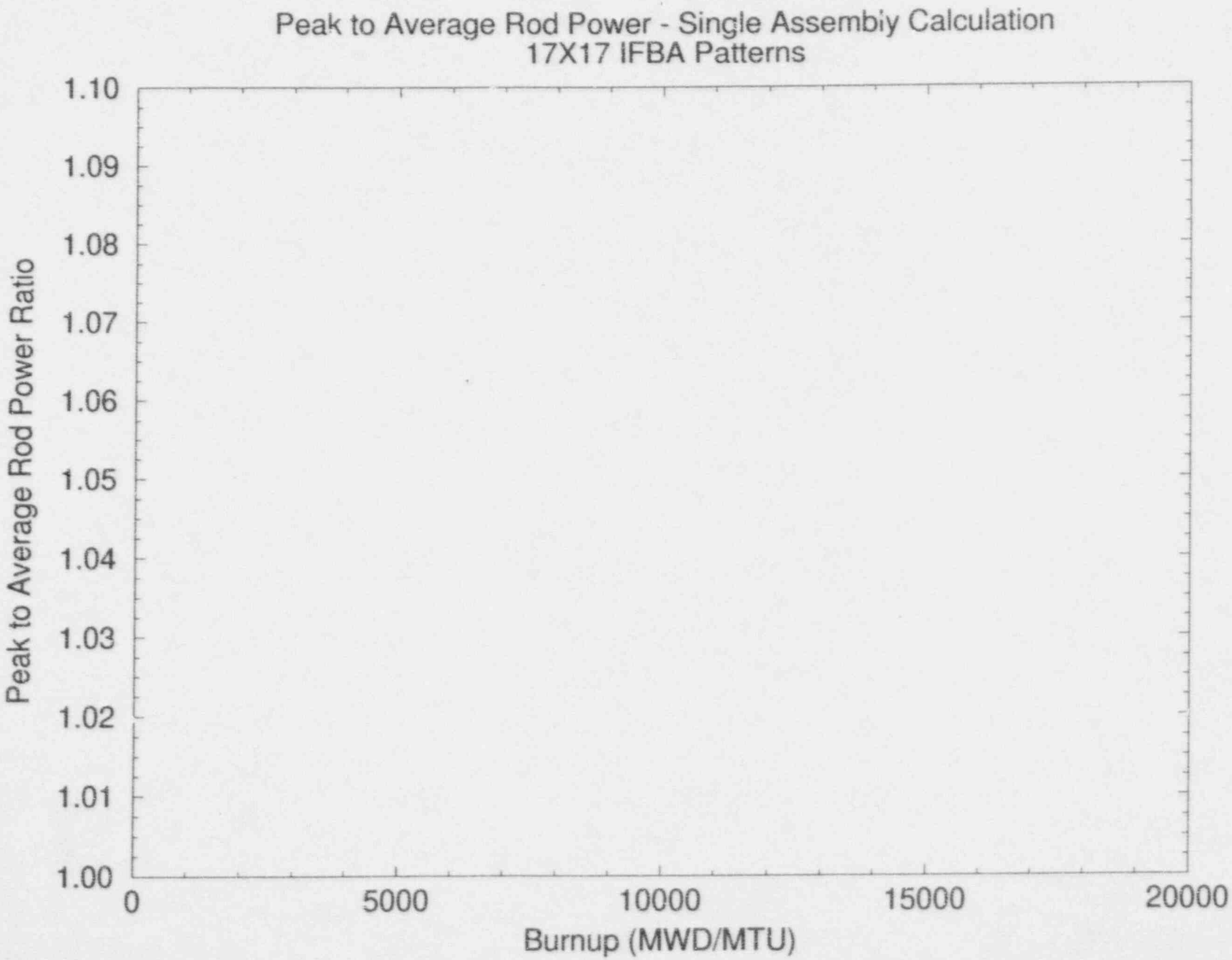
☒ Guide Tube or Instrument Tube

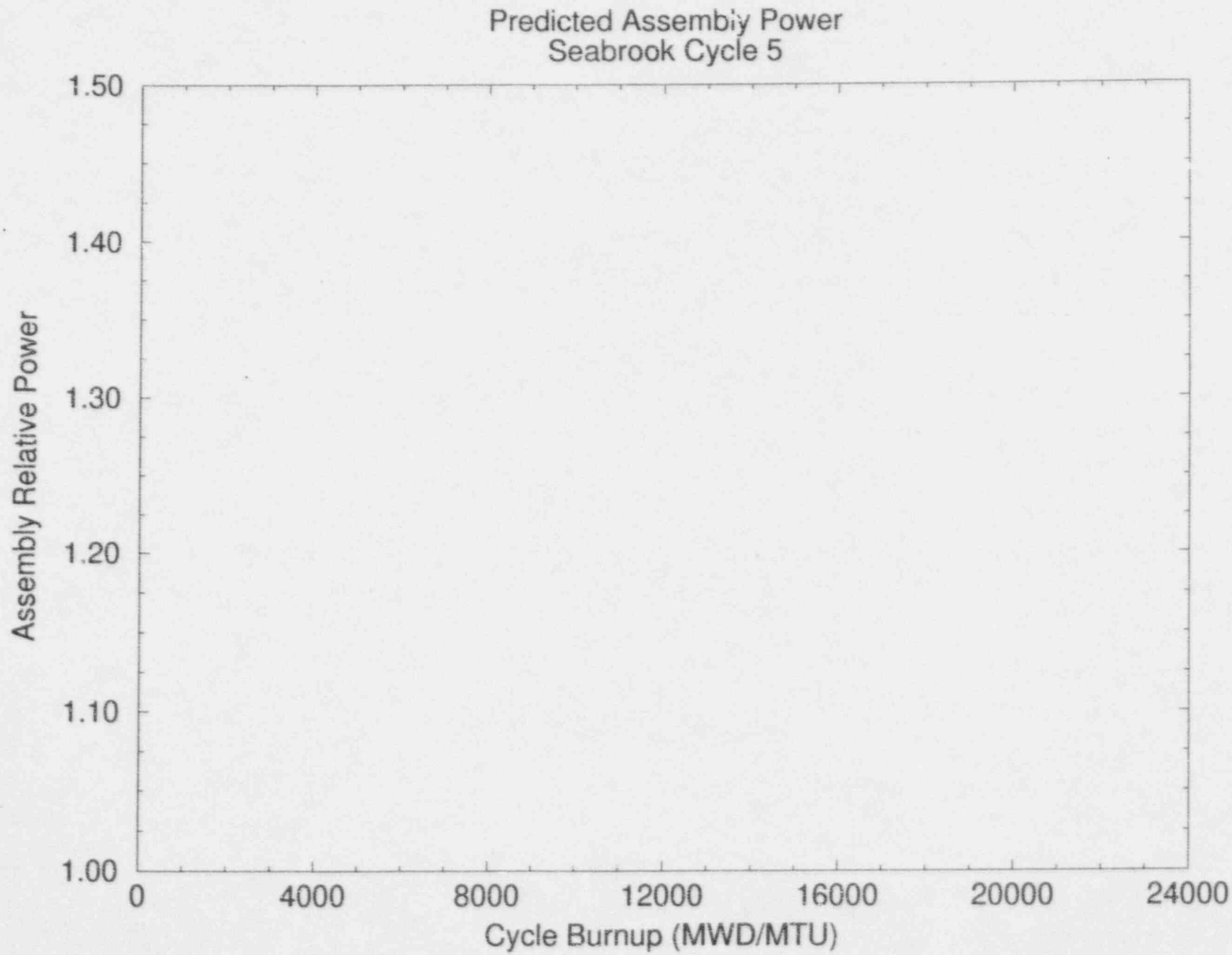
Fuel Assembly Orientation



• Reference Hole
○ Core Pin Hole
⁄ Holdown Bar

NOTE: Figures are Top View


Peak to Average Rod Power - Single Assembly Calculation
17X17 IFBA Patterns
Peak to Average Rod Power Ratio
1.10
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1.00
0
5000
10000
15000
20000
Burnup (MWD/MTU)



Predicted Assembly Power
Seabrook Cycle 5
1.50
1.40
1.30
1.20
1.10
1.00
Assembly Relative Power
0
4000
8000
12000
16000
20000
24000
Cycle Burnup (MWD/MTU)

Action Plan

- Complete in-depth inspection data evaluation
- Gather additional data from fuel rods at site
  - cladding oxide, crud sampling, eddy current, profilometry

Action Plan (con't)

- Check for similarities in fabrication with leaking rods from other sites with similar failure characteristics
- Evaluate similarities with failures at other sites
  - leaking fuel with hydride only indications
  - Other fuel
- Evaluate need for hot cell or other tests to support mechanism determination

Action Plan (con't)

- Power History Assessment
  - Steady State Power Histories
    - Summarize existing power histories
    - cross-check with Westinghouse methods
  - Define any transient duty
  - Evaluate impact of core tilt and AOA
  - Compare duty with In-core measurements
  - Compare rod power histories in cycle 5 to prior cycles
  - Compare leaking with non-leaking
  - Compare leaking with plants with similar fuel
  - Compare leaking with plants with higher duty (and different fuel designs)

Schedule for 1997

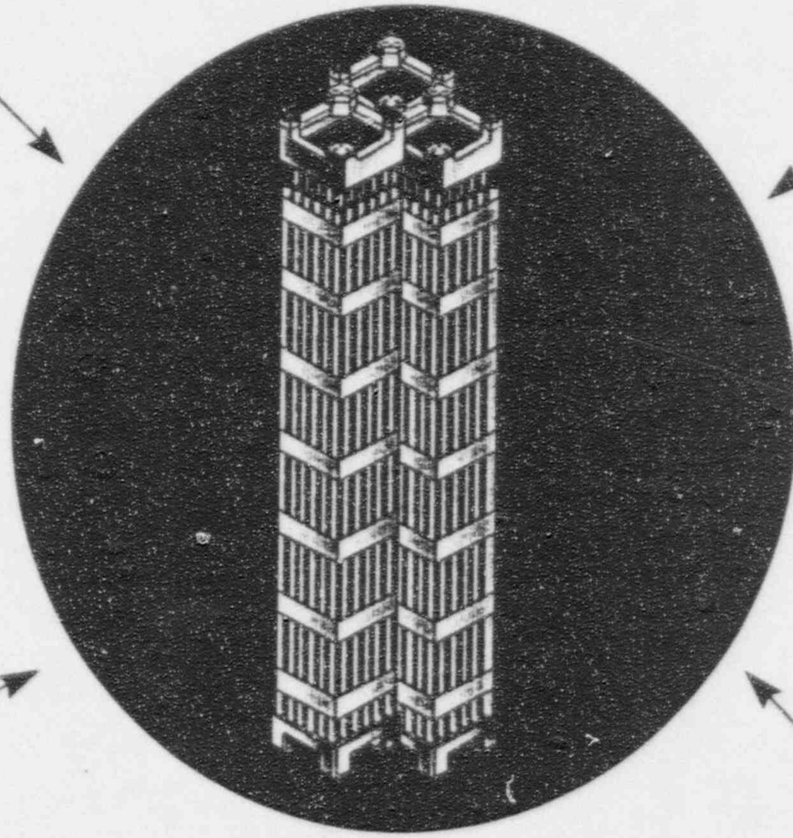
- Westinghouse root cause team formed
- June/July - In-depth data evaluation
- July/August - Gather additional fuel rod data at site
- July/August - Assessment of cycle 5 power history
- July/August - Fabrication similarity review
- September - Update NRC on investigation status

Fuel Improvement Programs Summary

Increased Inspection and PIE

Comprehensive Testing

Advanced Design Techniques



Customer Involvement

Licensee and University Cooperation

Use of LTAs

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Freon loop status

- Westinghouse DNB Freon loop was constructed at Penn State's Applied Research Laboratory (ARL)
- Loop was accepted for testing by Westinghouse on August 26, 1996
- To date, two DNB test have been completed (V5H on 20 in. spacing, and V5H on 10 in. spacing w/IFM's)
- Results trend as expected for most power levels
- Further tests planned to establish and validate the use of freon for DNB scoping

Flow visualization update

- Objectives
  - Characterize flow fields produced by mixing vanes
  - Help identify key flow parameters for DNB performance and relationship to grid features
- Test Data
  - Video
  - Subchannel total and partial velocities
  - Pressure drop

Flow Visualization Update

- Status to date
  - Two benchmark tests have been recently completed (V5H and MV5H 5x5 bundles)
    - Form the basis for future comparisons
  - Parametric studies of springs, vanes and advanced concepts planned

Inspection Plan Priorities

- Improve Fuel Performance
- Expand Capabilities of Engineering Models
- Support High Duty Cycles

Summary

- Westinghouse has Fuel Improvement Programs under way and is continuing to invest in technology.
- Customer involvement is required for the Fuel Development Programs
- Early performance data on improvements will be obtained through the use of Lead Test Assemblies (LTA)
- Fuel follow is integral to assess desired performance

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