FRAMATOME ANP

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Fuel Performance Meeting

Lynchburg, VA
July 30, 2003

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Fuel Performance Meeting Agenda
NRC and Framatome ANP – July 30

- *Welcome (Freeman)*
- *Tour of MAR Fuel Fabrication Facility (Carter/Ford)*
- *Generic Design Criteria (Holm)*
- *Plans for Future Topical Reports (Holm)*

Generic Design Criteria

Jerry S. Holm
Product Licensing Manager

Generic Design Criteria

NRC Approved Topical Reports

B&W Plants

- BAW-10179(P)(A), Safety Criteria and Methodology for Acceptable Cycle Reload Analysis

Westinghouse and Combustion Engineering Plants

- EMF-92-116(P)(A), Generic Mechanical Design Criteria for PWR Fuel Designs

General Electric Plants

- ANF-89-98(P)(A) Revision 1 and Supplement 1, Generic Mechanical Design Criteria for BWR Fuel Designs

Generic Design Criteria

The purpose of EMF-92-116(P) is stated on Page 1-1 of the report as follows:

"The purpose of this report is to present for NRC review and acceptance the generic mechanical design criteria for SPC PWR fuel designs. With NRC acceptance, PWR fuel designs which meet these design criteria will not need to be submitted to the NRC for explicit review and approval. Compliance with the design criteria would constitute approval."

Generic Design Criteria

- *Changes are acceptable when criteria are satisfied*
- *Examples of minor design changes are:*
  - *A change in the attachment of the HTP spacer to the guide tubes*
  - *A change in the strip thickness of the HTP spacer*
  - *A change in cladding thickness*
  - *The first use of an assembly design feature previously irradiated in conjunction with one lattice (i.e., 14x14) in a different lattice (i.e., 17x17)*
  - *A change in enrichment*
  - *A change in gadolinia-bearing rod locations*
- *Examples of design changes which constitute "new fuel designs" are:*
  - *New cladding material*
  - *A spacer with a new functional mixing behavior or new rod support mechanism (in the past, the shift from Bi-metallic to HTP spacer)*
  - *A change which would alter the fuel behavior relative to the NRC-approved models, e.g., rod growth, assembly growth, or clad corrosion*

Generic Design Criteria

- *NRC initiated concept*
- *Part of a larger strategy*
  1. *Minimize License Amendment Requests (LARs)*
  2. *Minimize NRC, licensee, and vendor resource requirements for LARs*

Generic Design Criteria

- *License Amendment Request/FANP First Reload*
  1. *Revise DNB Safety Limit based on NRC approved correlation*
  2. *Revise list of topical reports used to support limits in Core Operating Limits Report*

PWR Methodology B&W Plants

Methodology	Topical Report	Schedule
Neutronics	BAW-10180(A), NEMO Neutronics Code	Approved
Thermal-Hydraulic	BAW-10156(P)(A), LYNXT Core Transient Thermal-Hydraulic Code	Approved
DNB	BAW-10143(P)(A), DNB Correlations for Mark-B Designs	Approved
DNB	BAW-10241, DNBR Correlation for HTP Correlation in LYNXT	Under Review
Statistical Core Design	BAW-10187(P)(A), Statistical Core Design Process	Approved
Non-LOCA	BAW-10193(P)(A), RELAP5/Mod2-B&W Safety Analyses	Approved
LOCA	BAW-10192(P)(A), Large and Small Break LOCA Evaluation Model	Approved
Design	BAW-10179(P)(A), Safety Criteria and Methodology for Acceptable Cycle Reload Analyses	Approved
Design	BAW-10227(P)(A), M5 Cladding	Approved
Fuel Performance	BAW-10162(P)(A), TACO3 Fuel Rod Code	Approved

PWR Methodology
Westinghouse & Combustion Engineering Plants

Methodology	Topical Report	Schedule
Neutronics	EMF-96-029(P)(A), PWR Neutronics Methodology Using SAV95	Approved
Thermal-Hydraulic	XN-NF-82-21(P)(A), Thermal-Hydraulic and Mixed Core Analysis	Approved
DNB	EMF-92-153(P)(A), DNBR Correlation for HTP Spacer	Approved
DNB	BAW-10244, The BWU Critical Heat Flux Correlations with XCOBRA-IIIC	Aug-03
Setpoint	EMF-92-081(P)(A), Statistical Setpoint/Transient Methodology for Westinghouse Type Reactors	Approved
Setpoint	EMF-1961(P)(A), Statistical Setpoint/Transient Methodology for CE Type Reactors	Approved
Non-LOCA	EMF-2310(P)(A), Non-LOCA Methodology Using S-RELAP5	Approved
LBLOCA – Realistic	EMF-2103(P)(A), Realistic LBLOCA Methodology Using S-RELAP5	Approved
SBLOCA – Appendix K	EMF-2328(P)(A), SBLOCA Methodology Using S-RELAP5	Approved
Design	EMF-92-116(P)(A), Generic Mechanical Design Criteria	Approved
Design	BAW-10240, M5 Cladding for RODEX2 and S-RELAP5 Methodologies	Under Review
Fuel Performance	ANF-81-58(P)(A), RODEX2 Fuel Rod Code	Approved

BWR Methodology

Topical Report Submittals

Jerry S. Holm

Product Licensing Manager

Topical Report Submittals

B&W Methodology

Methodology	Topical Report	Schedule
DNB	BAW-10241(P), DNBR Correlation for HTP Correlation in LYNXT	Under Review
Neutronics	BAW-10242(NP), Zero Power Physics Test	Under Review
Design	BAW-10179(P) Revision 5, Reload Methods	Under Review
Design	BAW-10179 Revision 6	Mar-04

Topical Report Submittals (continued)

W & CE Methodology

Methodology	Topical Report	Schedule
Non-LOCA	EMF-2310 Revision 1, S-RELAP5 for PWR Non-LOCA Modified Boron Dilution Methodology	Aug-03
MOX	BAW-10238(P), MOX Fuel Design	Under Review
MOX	BAW-10231(P), COPERNIC for MOX	Under Review
MOX	BAW-10248, Modifications to LOCA Methodology for MOX	Mar-04
DNB	BAW-10244, The BWU Critical Heat Flux Correlations with XCOBRA-IIIC	Aug-03
Design	BAW-10240, M5 Cladding for RODEX2 and S-RELAP5 Methodologies	Under Review
Design	BAW-10239, Advanced Mark-BW Design	Under Review

Topical Report Submittals (continued)

Topical Report Submittals (continued)

Fuel Performance Meeting

Lynchburg, VA
July 31, 2003

Non-proprietary

FRAMATOME ANP

Fuel Performance Meeting Agenda
NRC and Framatome ANP – July 31

- *Welcome (Matheson)*
- *Introduction and Purpose (Mallay)*
- *Description of Framatome ANP (Organization, Facilities, and Services) (Mallay)*
- *Description of Current Fuel Designs and Key Features*
  - *PWR (Haibach)*
  - *BWR (Garner)*
- *New Fuel Designs (Garner)*
- *Recent Fuel Performance Experience (Willse)*
- *Lead Test Assemblies (Strumpell)*
- *Description of Recent Post-Irradiation Examinations (Strumpell)*
- *Extended Burnup Database and Schedule (Willse)*

Introduction and Purpose

Jim Mallay

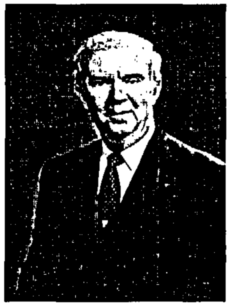
Introduction

- Framatome ANP participants
- Outline of discussion
  - Current fuel designs
  - New fuel designs
  - Recent experience
  - Fuel development
- Objectives
  - Understanding Framatome ANP's fuel design
  - Exchanging ideas and expectations on fuel issues
  - Open communication; ask questions

Framatome ANP: 13,000 Employees Worldwide

• Engineering • Manufacturing • Services • Offices

U.S. Executive Team



President & CEO
Tom Christopher

Senior VP
I&C and Electrical
Tom Weir

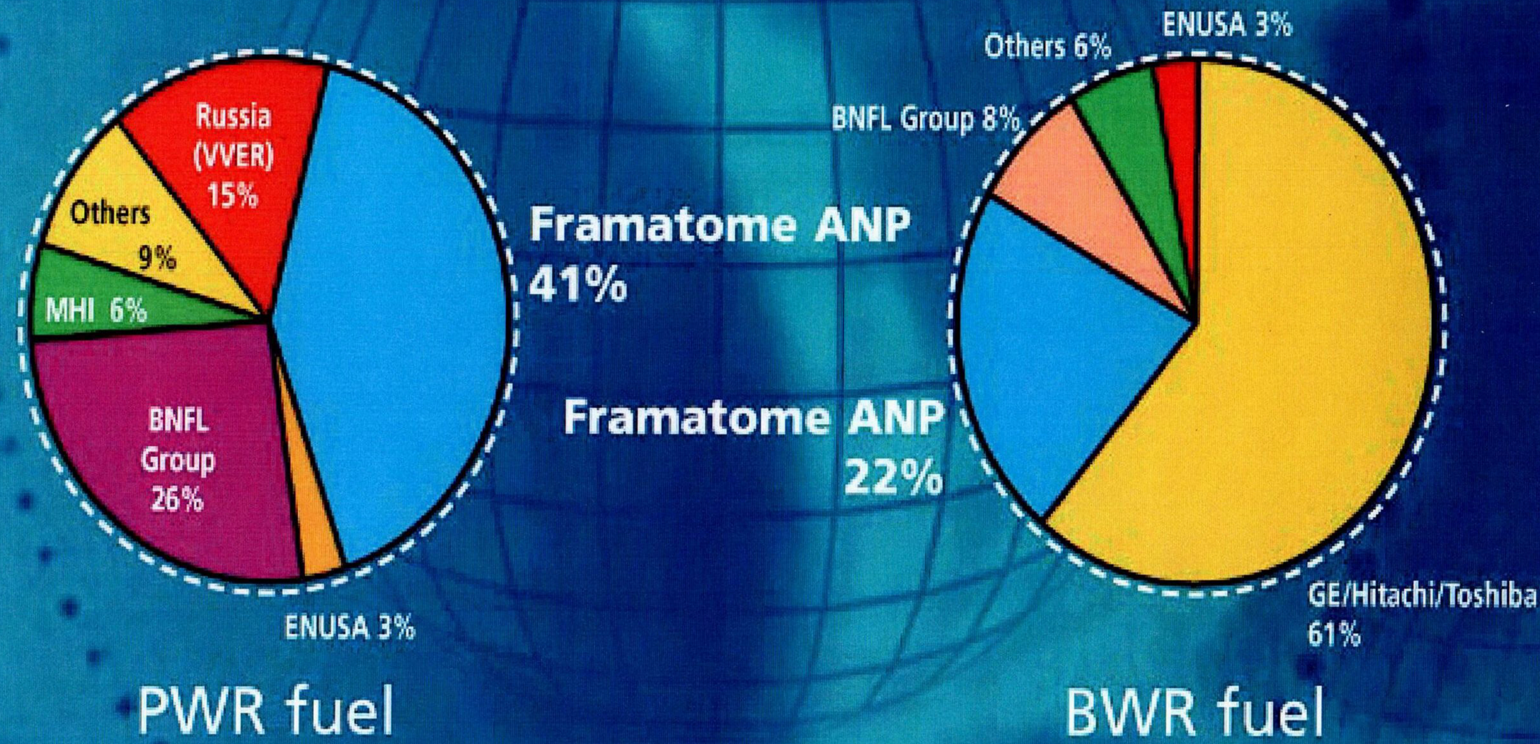
Senior VP
Projects & BWR Integration
Don Janecek

Senior VP
Nuclear Engineering
Ray Ganthner

Senior VP
Nuclear Fuel
John Matheson

Nuclear Fuel : Optimizing the cycle

From the manufacture of zirconium alloy to the delivery of fuel assemblies, **Framatome ANP** is the world leader in fuel for nuclear power reactors and research reactors.



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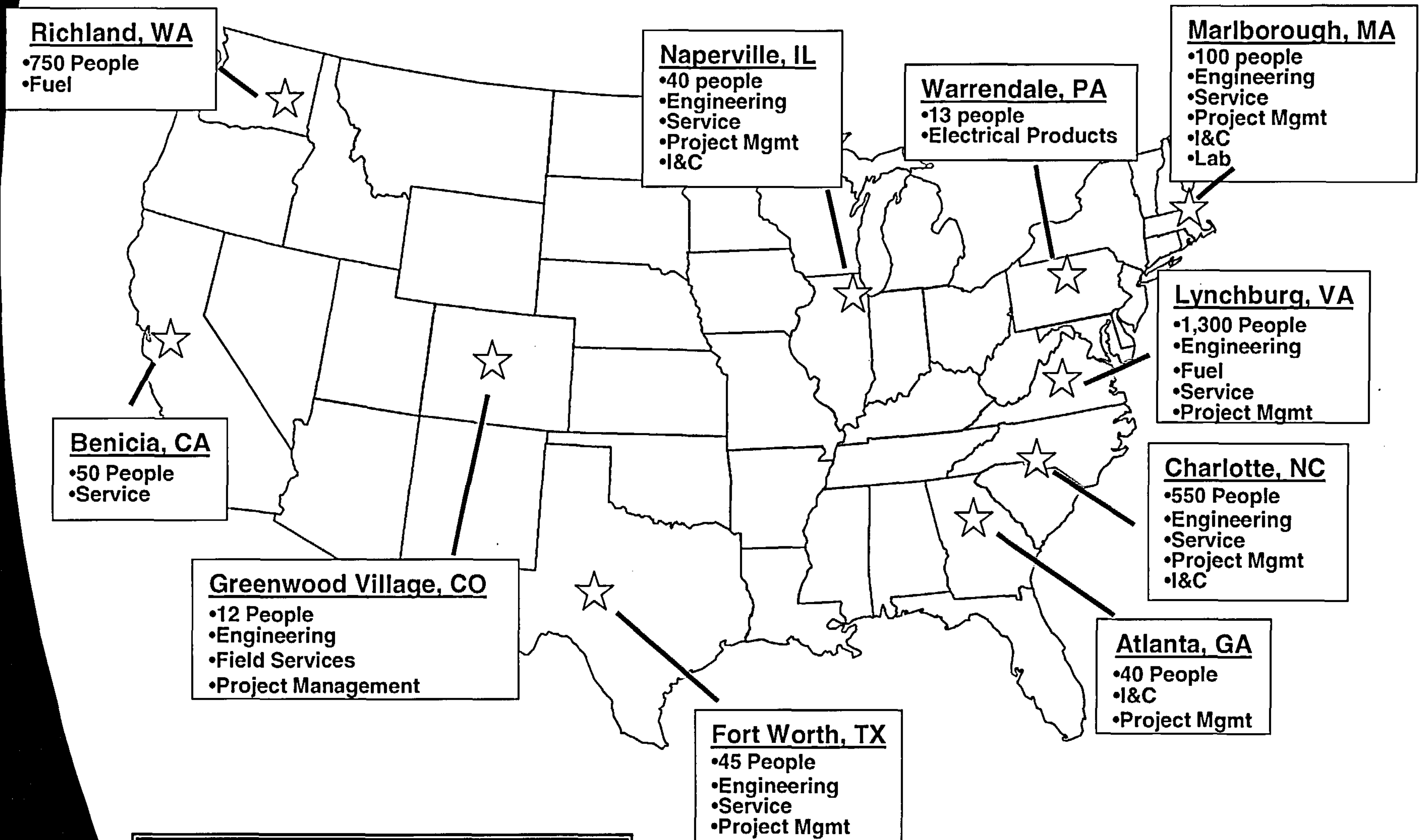
C02

Framatome ANP in the U.S.



Substantial U.S. Presence

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Description of Current U.S. PWR Fuel Designs, Key Features, and Enhancements

Brian Haibach

Agenda

- **Advanced Mark-BW Design Review**
  - Experience and performance history
  - Design features
  - Performance enhancements
  - Future milestones
- **Mark-B Design Review (B10, B12, and B11)**
  - Design features and milestones
- **HTP Design Review**
  - Mechanical design summary
  - Design features
  - Future milestones
  - CE specific update

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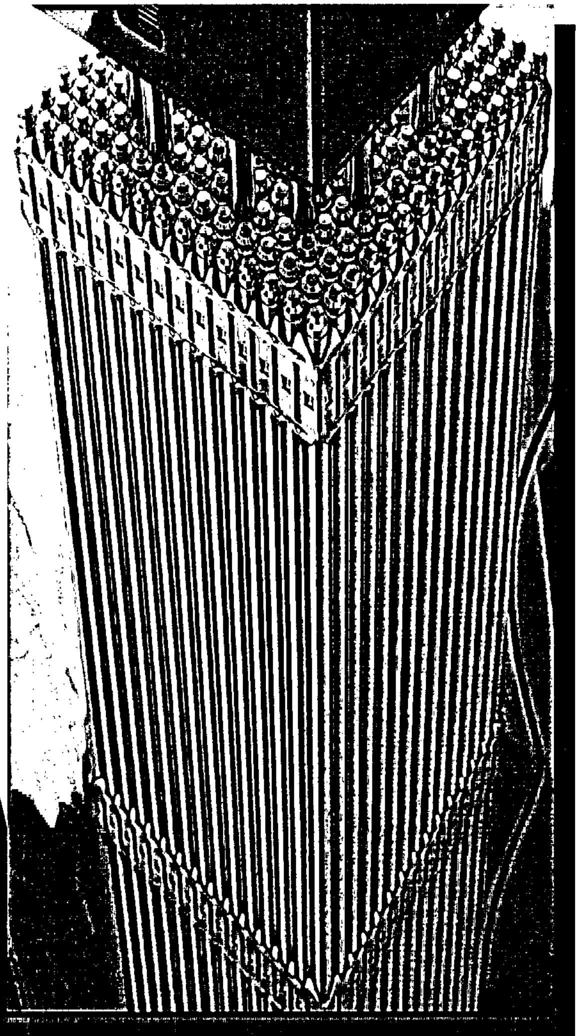
Mark-BW Fuel Assembly Experience

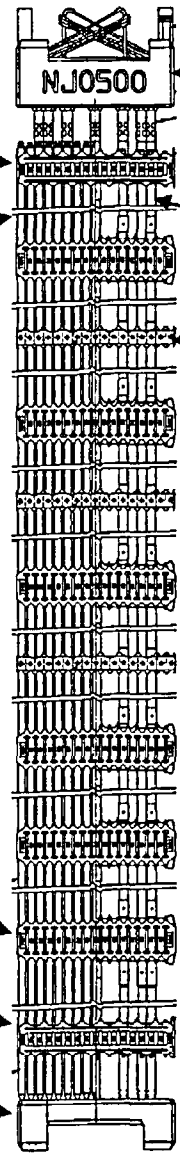


- *Maximum FA discharge burnup is 53,000 MWd/mtU*
- *Average discharge burnup for 2002 is > 45,000 MWd/mtU*
- *60 fuel assemblies have > 50,000 MWd/mtU*
- *Over 2650 fuel assemblies irradiated*

Mark-BW Performance History

- Nine (9) confirmed fuel rod failures; 1 additional estimated
  - 2 unidentified failures
    - Specific pin not found or unknown failure mechanism
  - 4 debris failures
    - Failures found in non- or partial TRAPPER cores
    - No failure in all TRAPPER cores
  - 1 no look
    - High probability to be manufacturing defect in end-cap weld
  - 1 creep collapse failure
    - Manufactured in 1991; pre x-ray fabrication
    - No reoccurrence
  - 1 fretting failure
    - Manufacturing defect lower Inconel grid; corrected
    - No reoccurrence

Advanced Mark-BW Design Features



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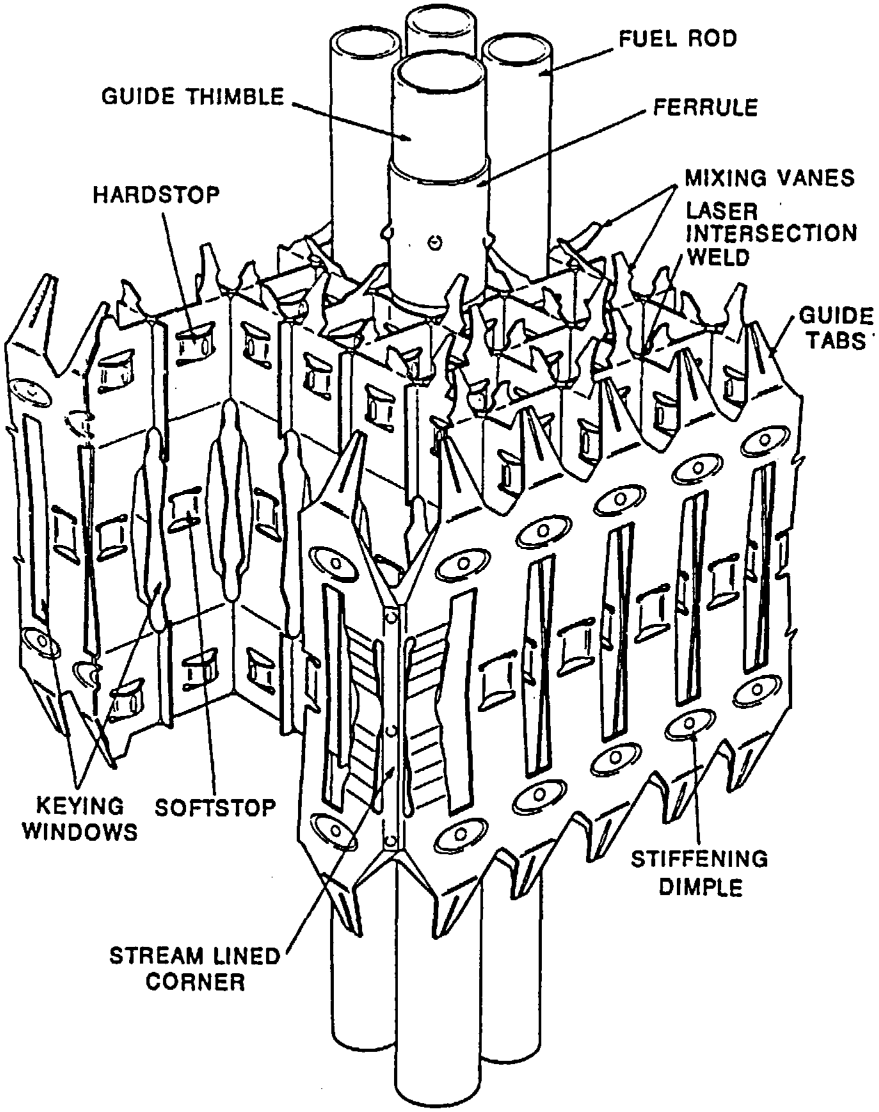
Advanced Mark-BW Spacer Grid



- Wide rod supports
- Floating intermediate grids
  - NRC has given FANP credit for reduced rod bow in its DNB licensing methodology

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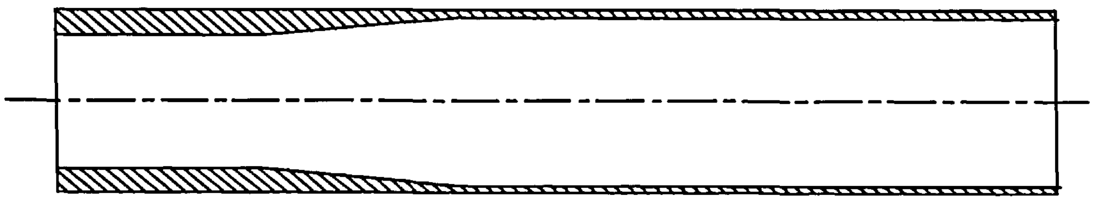
Advanced Mark-BW Enhancements

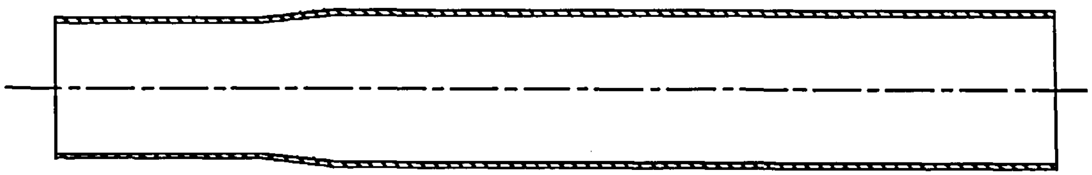
- *M5™ structure (fuel rods, GT, and intermediate grids)*
  - *Low fuel assembly growth reduces integrated loads over lifetime*
  - *M5™ corrosion and growth is insensitive to duty*
    - *More predictable and well behaved data, even at high burnup*
  - *Low hydrogen pickup guards against hydride related failure*
- *M5™ fuel rod modifications*
  - *Fuel rod lengthened to increase plenum volume*
  - *Reduced cladding thickness and increase pellet diameter for heavier loading (460 to 466 kgU)*
- *M5™ mid-span mixing grids*
  - *Provides additional thermal margin*
  - *Addresses fuel assembly compatibility in transition*

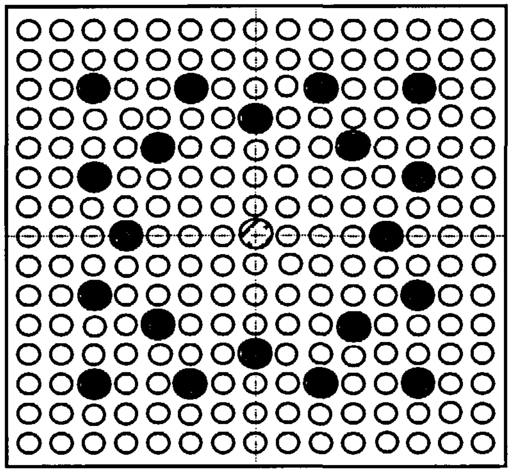
Guide Tube Upgrade for Extended BU Applications

MONOBLOC™



Original Configuration





Fuel Rod
Guide Tube
Instrument Tube

Purpose of the MONOBLOC™?

- *Increased lateral stiffness*
- *Reduced FA bow & twist*
- *Increased RCCA insertion margins*

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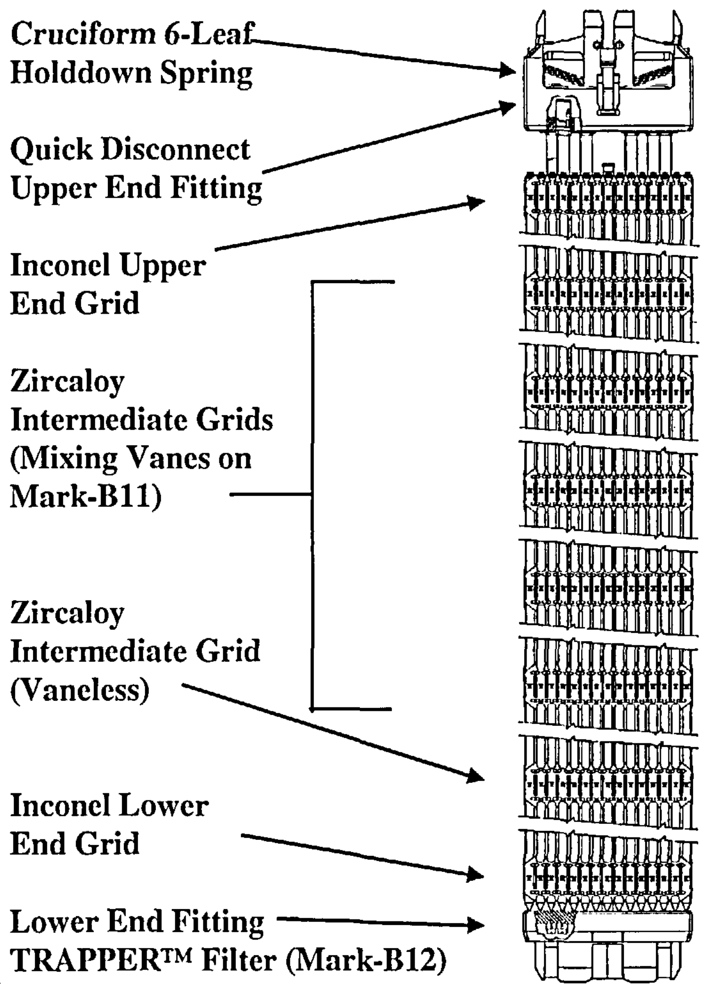
Advanced Mark-BW: Future Milestones

Advanced Mark-BW LTAs: Key Milestones

	Initial Loading	EOC 1 PIE	EOC 2 PIE	EOC 3 PIE	EOC 4 PIE

Advanced Mark-B Design Features



Mark-B10K/B12

- *TRAPPER™ debris filter lower end fitting*
- *Heavy loaded fuel rod (0.430")*
- *M5™ advanced alloy cladding & guide tubes*
- *Cruciform 6-leaf holddown spring*
- *Optional quick disconnect upper end fitting*

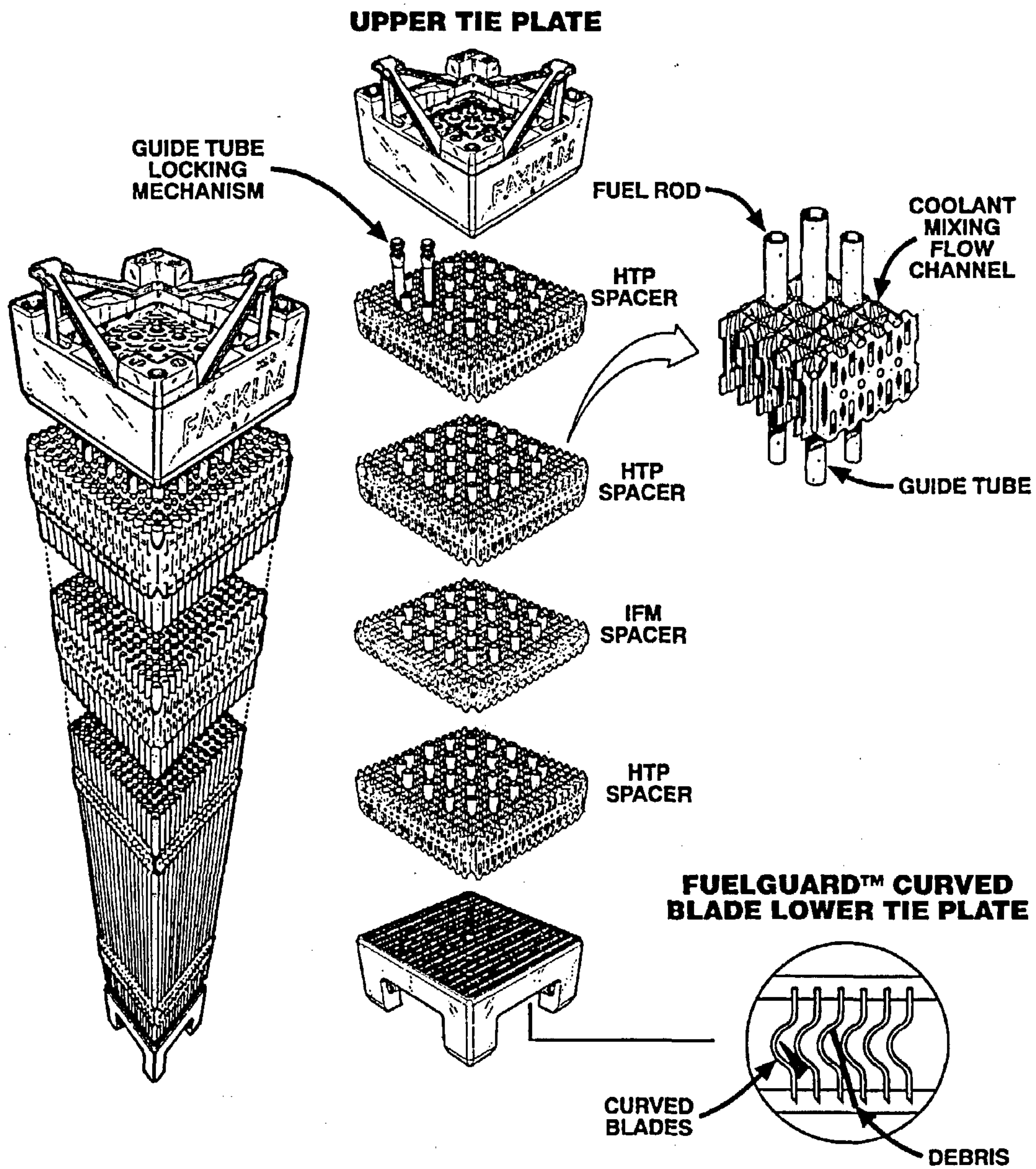
Mark-B11

- *Plug-in-grid debris filter*
- *Reduced diameter (0.416") fuel rod*
- *M5™ advanced alloy cladding*
- *High thermal margin flow mixing grids*
- *Cruciform 6-leaf holddown spring*
- *Quick disconnect upper end fitting*

HTP Mechanical Design Summary

- Design variants for W17x17, W15x15, W14x14, CE14x14, CE15x15, and now B&W15x15 reactors
- Design Features
  - M5 Fuel Rod Cladding
  - Zr-4 HTP Spacers and Intermediate Flow Mixers
  - FUELGUARD™ Lower Tie Plate

HTP Fuel Assembly



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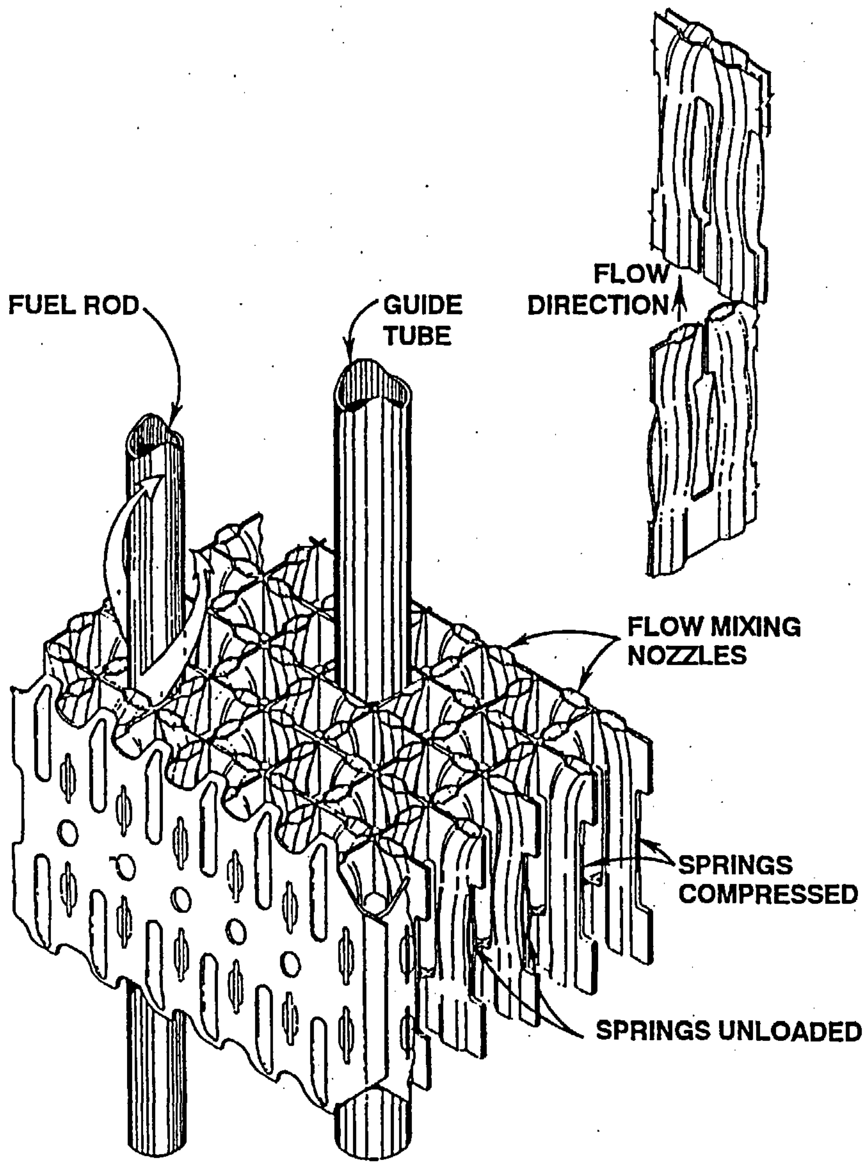
HTP Spacer Grid

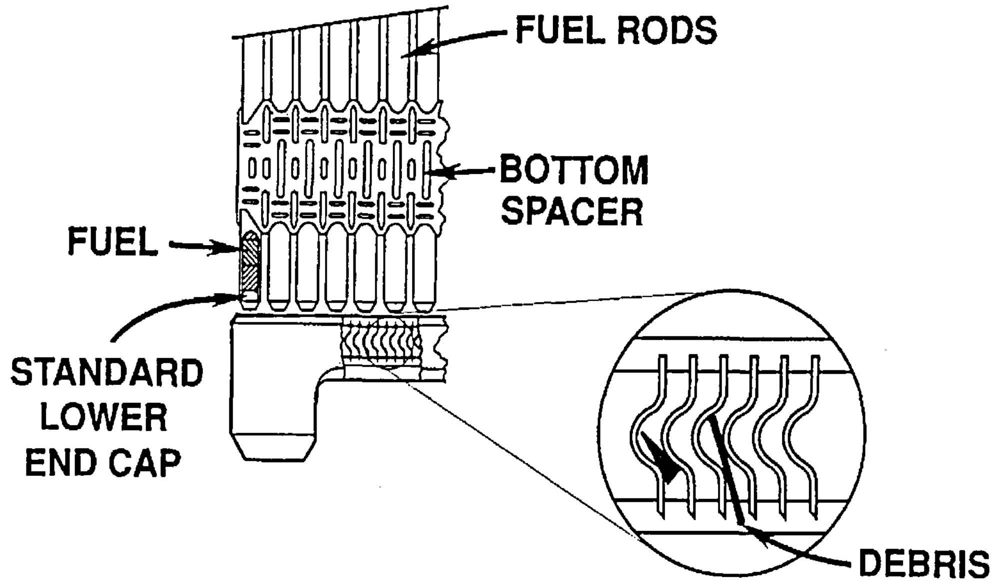
- *"Line contact" rod support system*
- *Robust construction*
- *Low flow resistance*
- *Channels for flow mixing*
- *FIV mitigation – springs in all lateral directions*



FUELGUARD™ Lower Tie Plate

▷ Curved Blade Design

- No direct "line of sight"
- Precludes debris, even straight wires
- Hydraulically clean - low pressure drop
- Reduction of inlet turbulence
- Adjustable thickness, pitch, and form to meet specific plant application requirements



HTP: Future Milestones

[ ]

HTP: Future Milestones

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HTP/CE Variant: Future Milestones

BWR Fuel Design Description

- Current Design
- Future Design

Norm Garner

Framatome BWR Fuel Experience
Status January 2003

	FA-Type	Total Number of Fuel Assemblies / Rods in Operation		Total		Maximum FA Burnup [MWd/kgU]
US, Mexico, & Far East Plants	ATRIUM-10*	3,082	280,462	3,330	303,030	45
	ATRIUM 9	3,949	284,328	4,942	355,824	45
	9x9-5	0	0	1,124	85,424	45
	9x9-1,2	984	77,736	6,176	487,908	47
	early fuel	0	0	7,812	501,045	43
European Plants	ATRIUM-10	2,776	252,588	3,246	295,358	71
	10x10-8	268	24,656	368	33,856	62
	ATRIUM 9	441	31,752	2,312	166,464	55
	9x9-5	170	12,920	1,724	131,024	51
	9x9-1,2	136	10,880	5,715	457,196	58
	early fuel	19	1,197	12,439	709,702	43
Totals	All Fuel Types	11,821	976,155	49,184	3,526,467	71
	ATRIUM-10	5,858	533,050	6,576	598,388	71

** Both Susquehanna units are operating with full cores of ATRIUM-10*

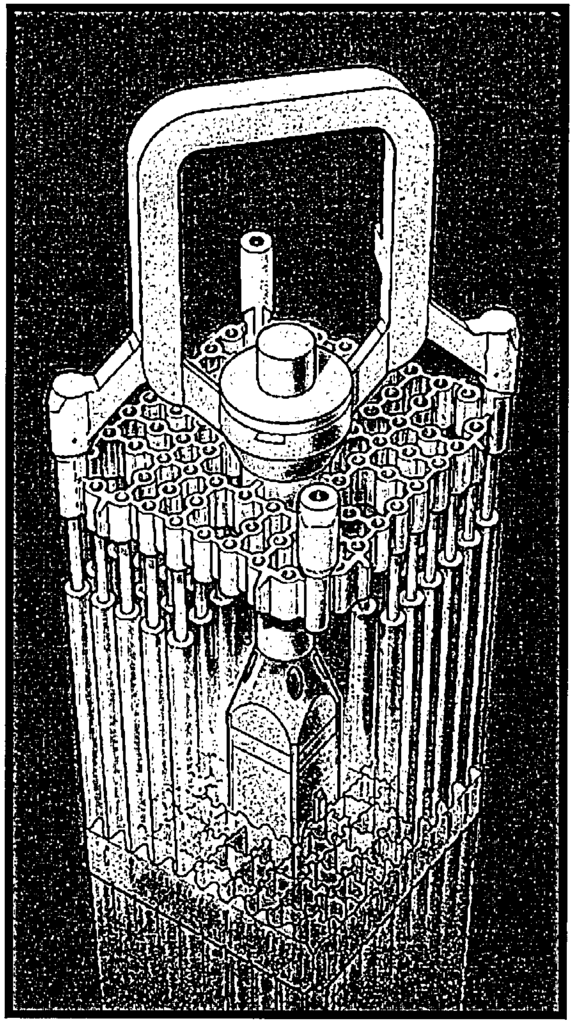
ATRIUM-10 Design Overview

- The ATRIUM-10 fuel design is currently supplied for all FANP US/Taiwan/Europe customers
- USNRC licensed for 62 GWd/MTU peak rod and 54 GWd/MTU peak assembly burnup
- The ATRIUM-10 has performed very well in high demand cycles for over a decade
  - Over 6,500 assemblies under irradiation in 25 BWRs worldwide
  - Power densities to 57 kW/liter (US BWRs currently range to 55 kW/l, projected to 58 kW/l for BWR/4,5 at 120% EPU)
  - Discharge exposure of 71 GWd/MTU achieved for lead fuel assemblies in a high demand plant

ATRIUM-10 Fuel Assembly Features

Key Features

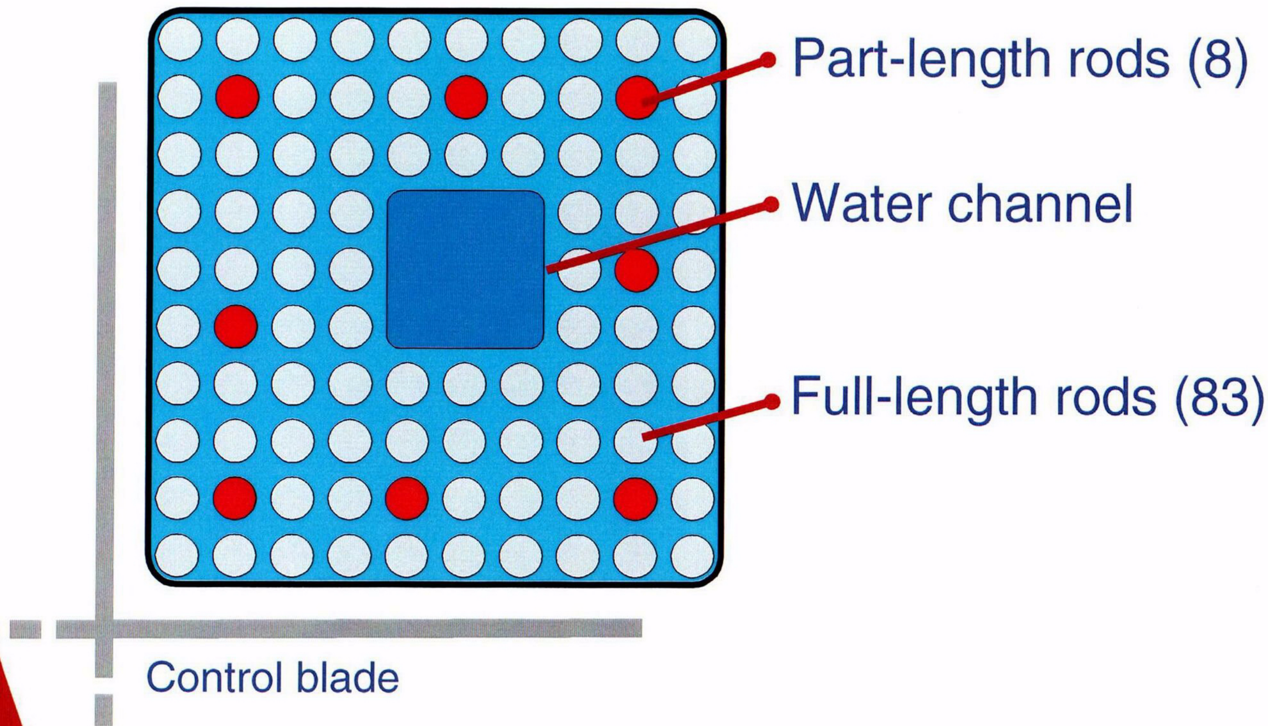
- Square Internal Water Channel
- Load Chain via Internal Channel
  - No tie rods or fuel rod compression springs
  - No structural load on fuel rods
- ULTRAFLOW™ Spacer
- FUELGUARD™ Lower Tie Plate

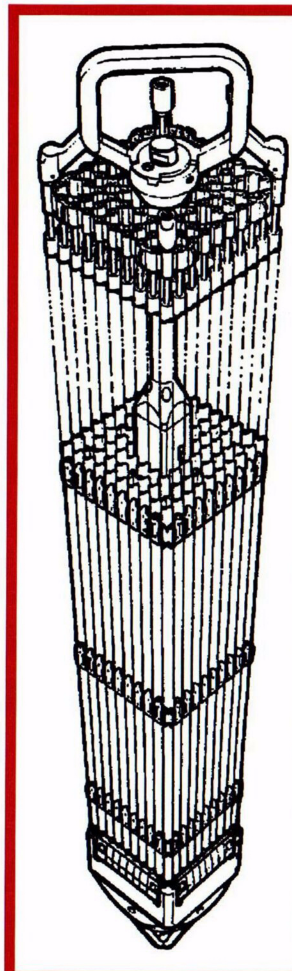


ATRIUM-10 BWR Lattice

Geometry provides for efficient moderator distribution

- ***Large central volume of unvoided water***
- ***Part-length rods improve thermal performance and cold reactivity characteristics***



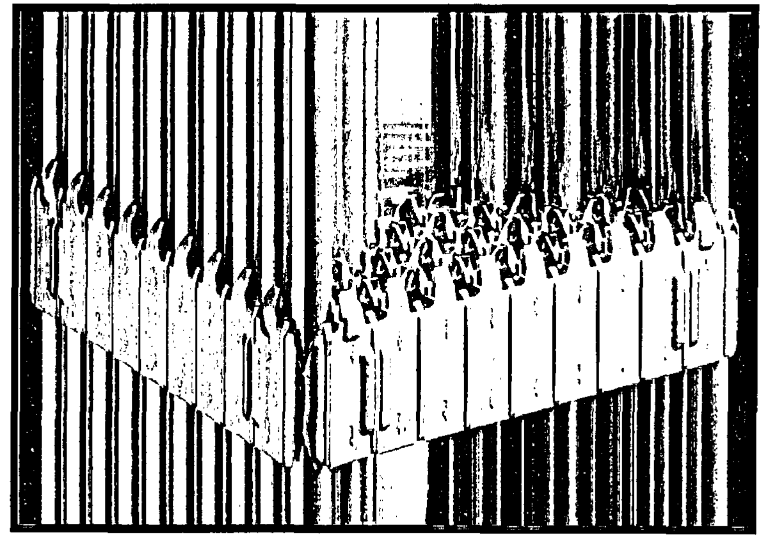


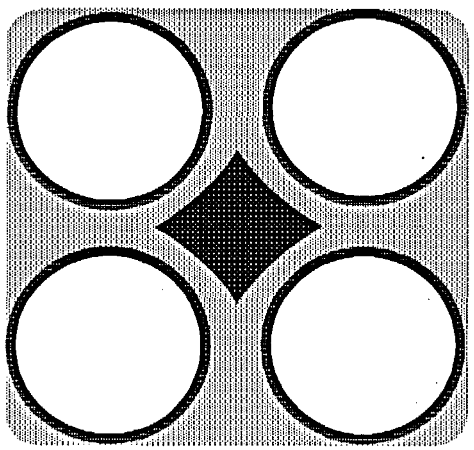
C03

ULTRAFLOW™ BWR Spacer

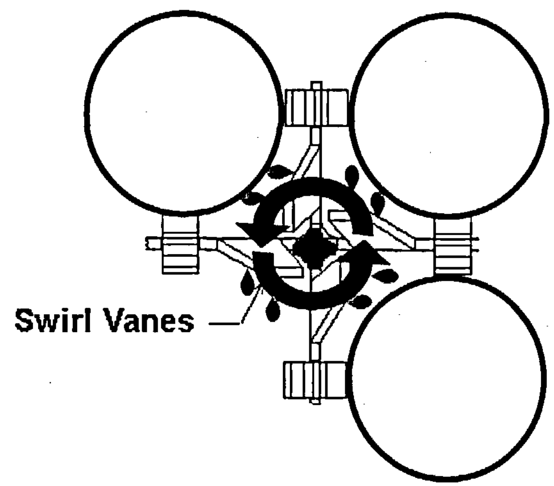
Spacer fabricated from Zircaloy strips with Inconel springs and integrated mixing features

- *Same basic design as used for ATRIUM 9 since 1987*





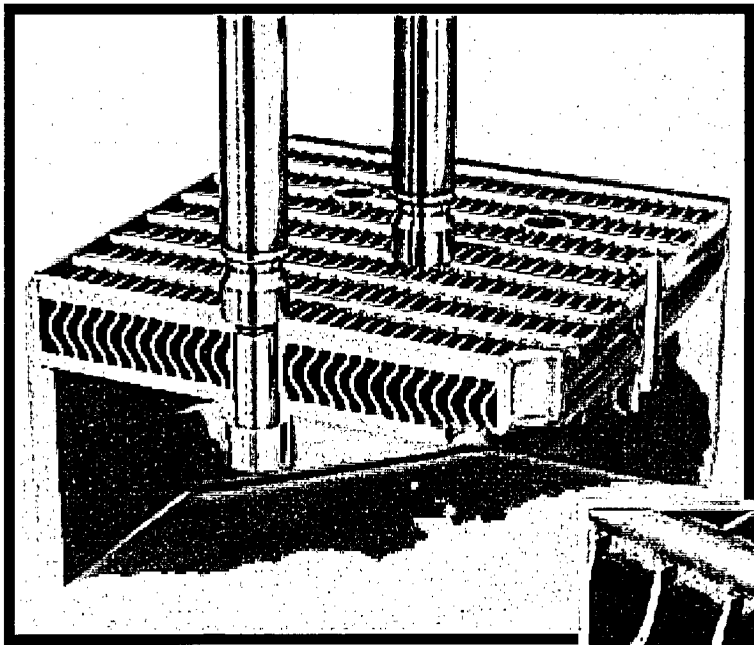
Liquid droplets concentrate in subchannel between rods



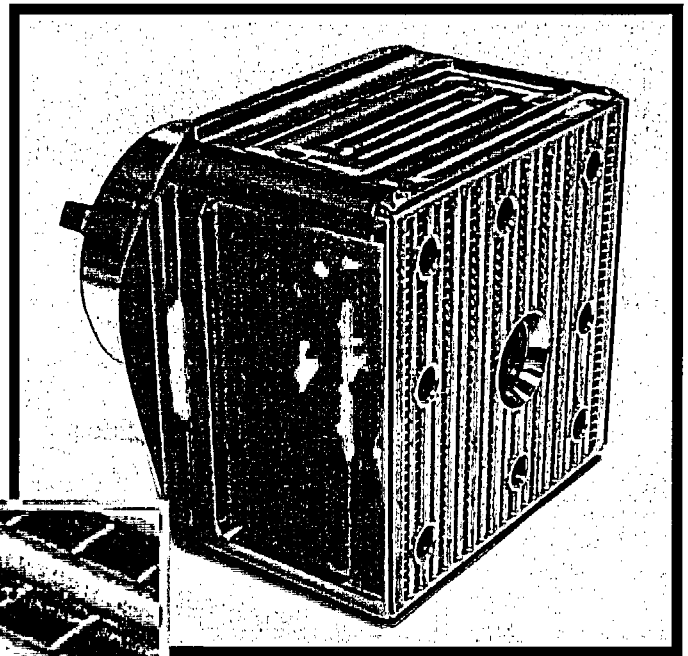
Swirl vanes redirect droplets onto liquid film on rod surfaces

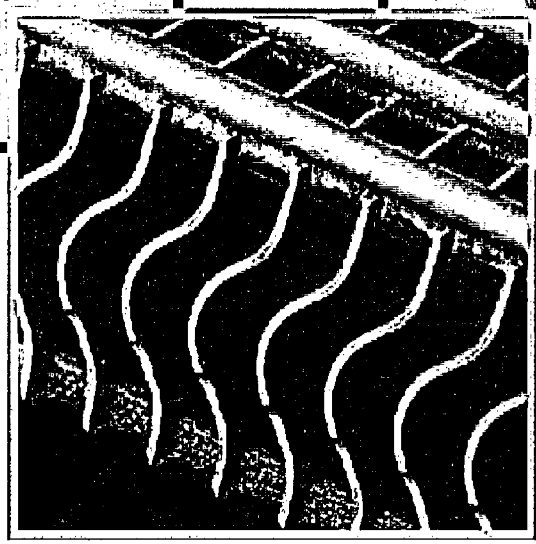
FUELGUARD™ Lower Tie Plate

PWR



BWR

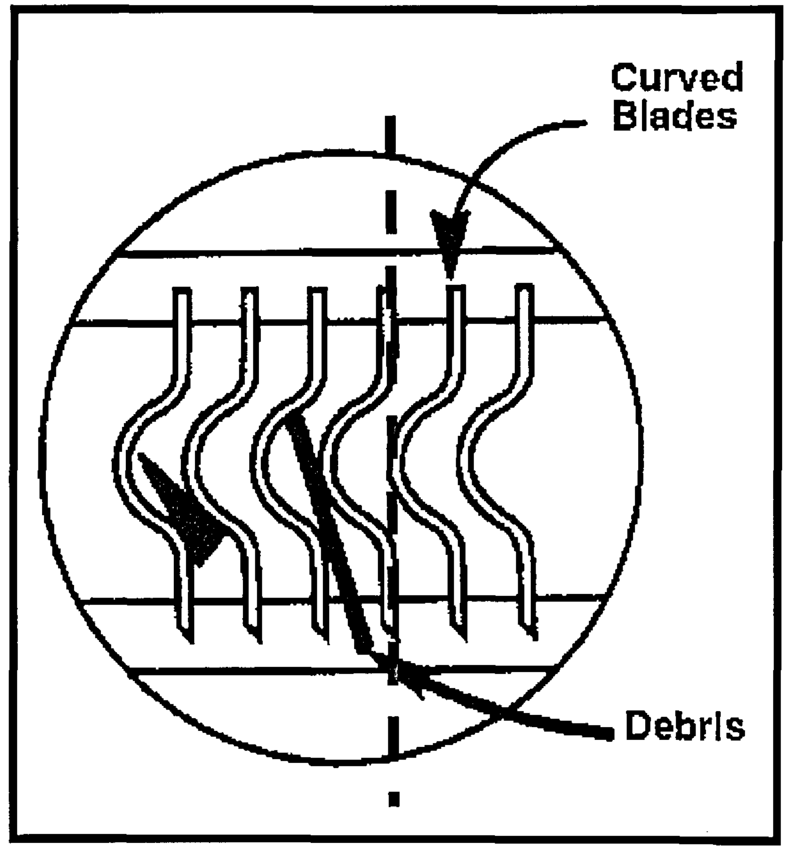




FUELGUARD™ Lower Tie Plate

Curved Blade Design

- *No direct "line of sight"*
- *Precludes debris, even straight wires*
- *Hydraulically clean - low pressure drop*
- *Adjustable thickness, pitch, and form to meet specific application requirements*



Next Generation Design for the BWR Market

Advanced ATRIUM-10 Development

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Why Pursue a New Design?

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Key Objectives of a New Design

- [

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Program History

- [

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Advanced ATRIUM-10 Design Features

- [

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Advanced ATRIUM-10 Design Features (continued)

Critical Heat Flux Performance
- CHF Testing Approach

- [

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Critical Heat Flux Performance
- Testing History

- [

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Other Testing

- [

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Program Schedule

- [

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Lead Use Assembly Approach

- [

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Fuel Reliability and Performance

John Willse

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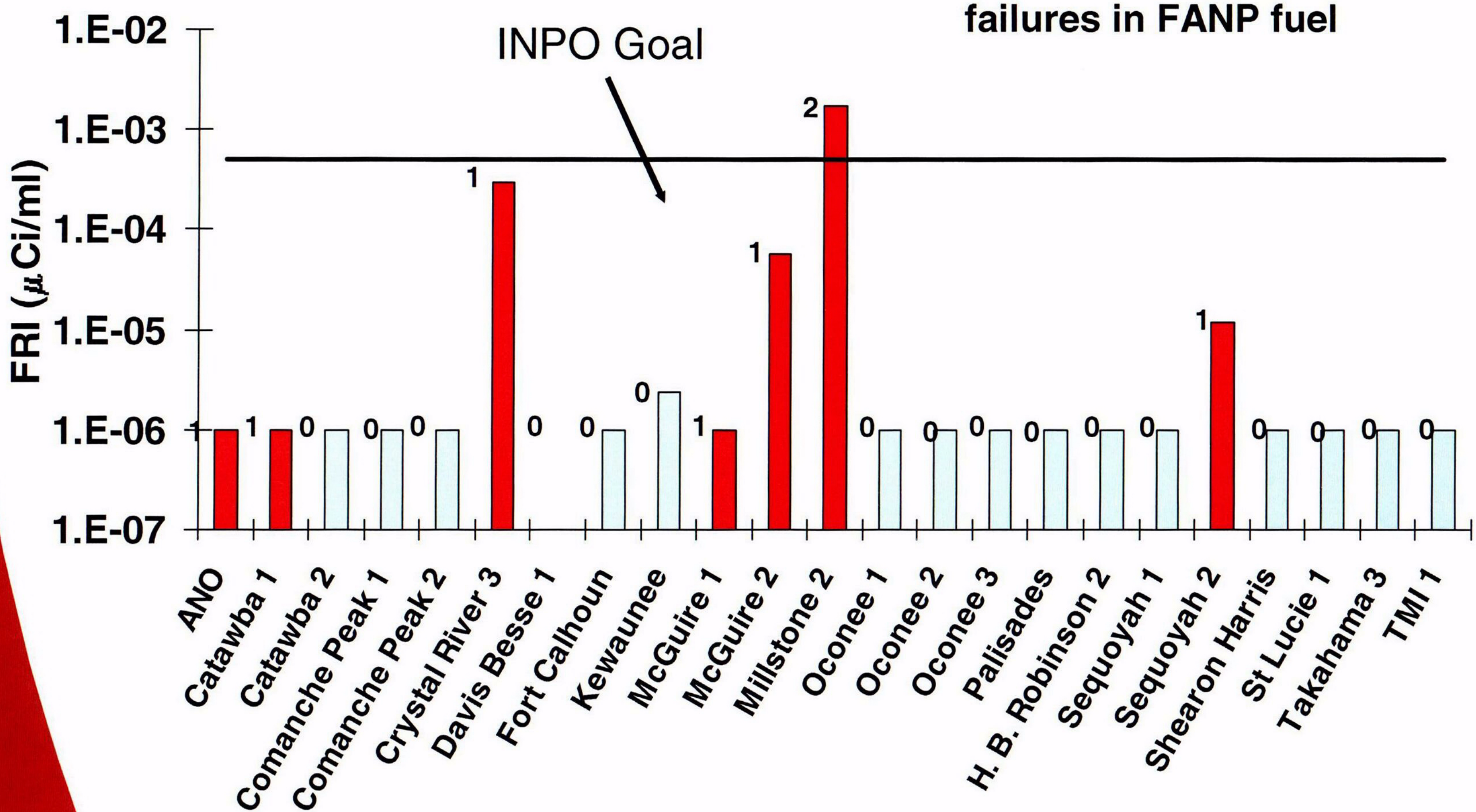
Agenda

- Fuel Performance Status
- Operational Issues
  - Damaged Spacer Grids
  - Slipped Spacer Grids
  - Stuck Fuel Assemblies
  - Crud Issues
  - Channel Bow Issues

Framatome ANP PWR Fuel Performance Status

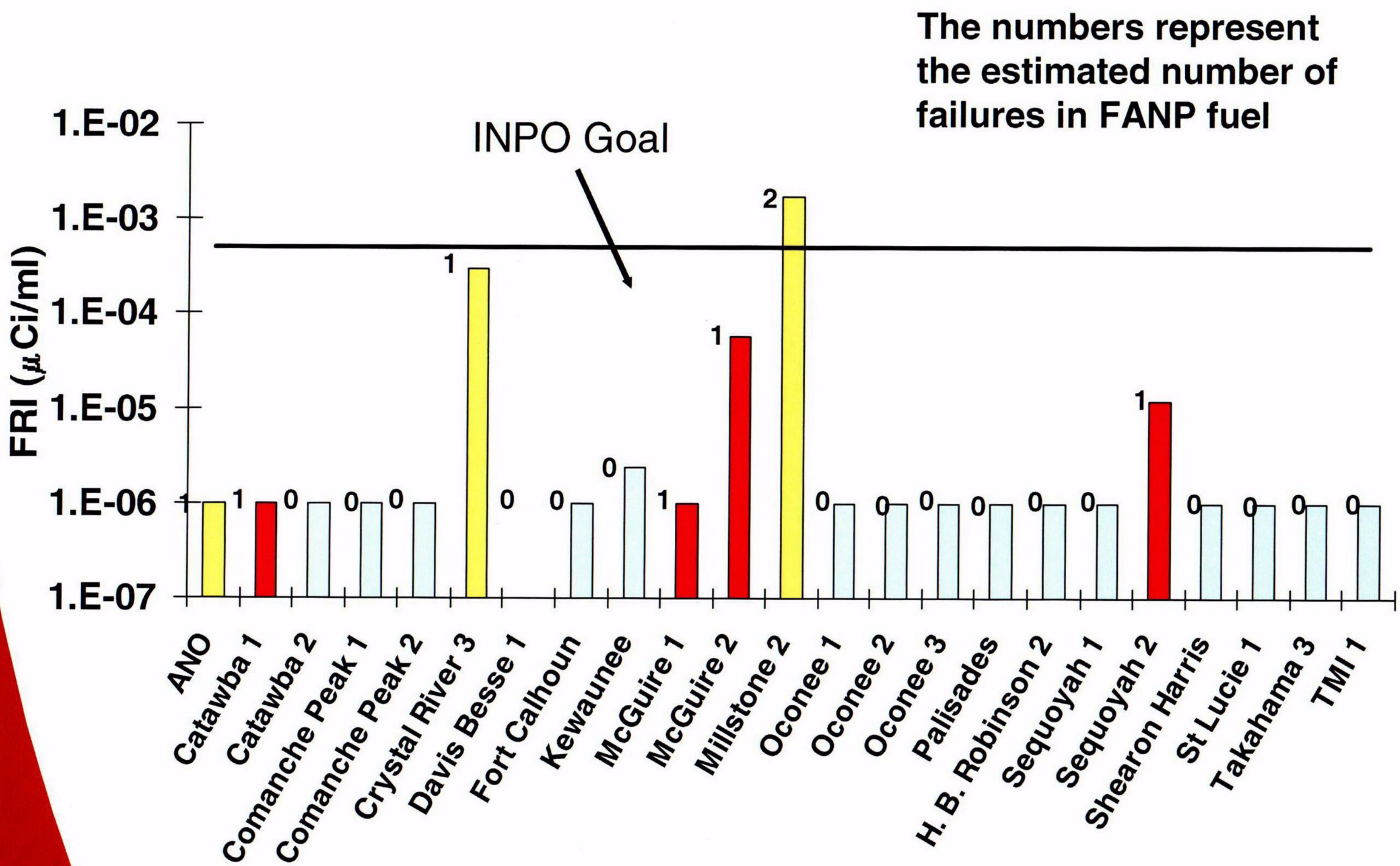
The numbers represent the estimated number of failures in FANP fuel



FRAMATOME ANP

C04

Framatome ANP PWR Fuel Performance Status



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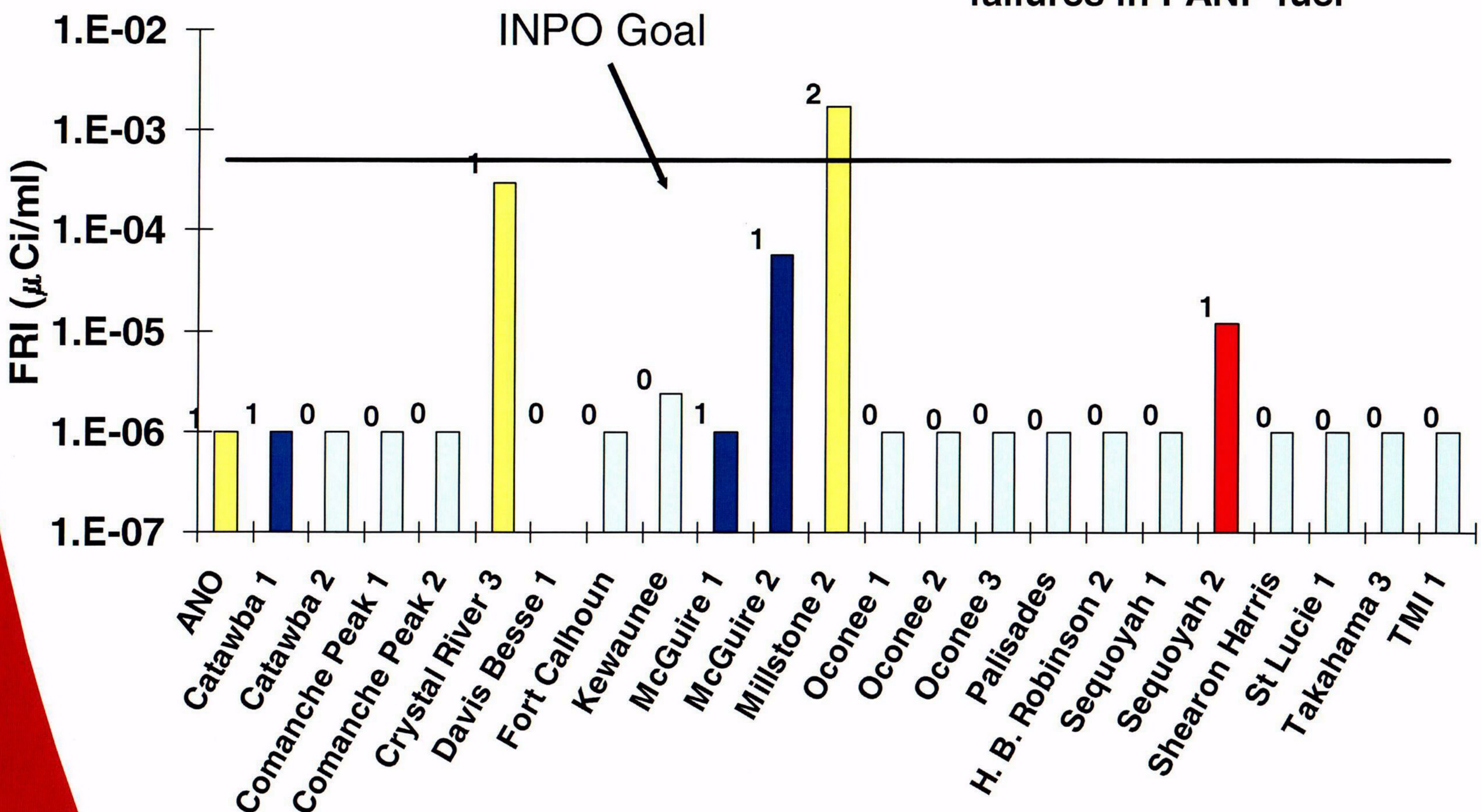
C05

Spacer Grid Fretting Failures

- *Plants in yellow are susceptible to spacer grid fretting failures in locations adjacent to the baffle plates*
- *New designs have been introduced that will eliminate this failure mechanism*
- *Unfortunately, the new design does not reside in the locations susceptible to failure until their third cycle of irradiation*
- *Some of these plants will continue to have failures for the next couple of cycles*

Framatome ANP PWR Fuel Performance Status

The numbers represent the estimated number of failures in FANP fuel



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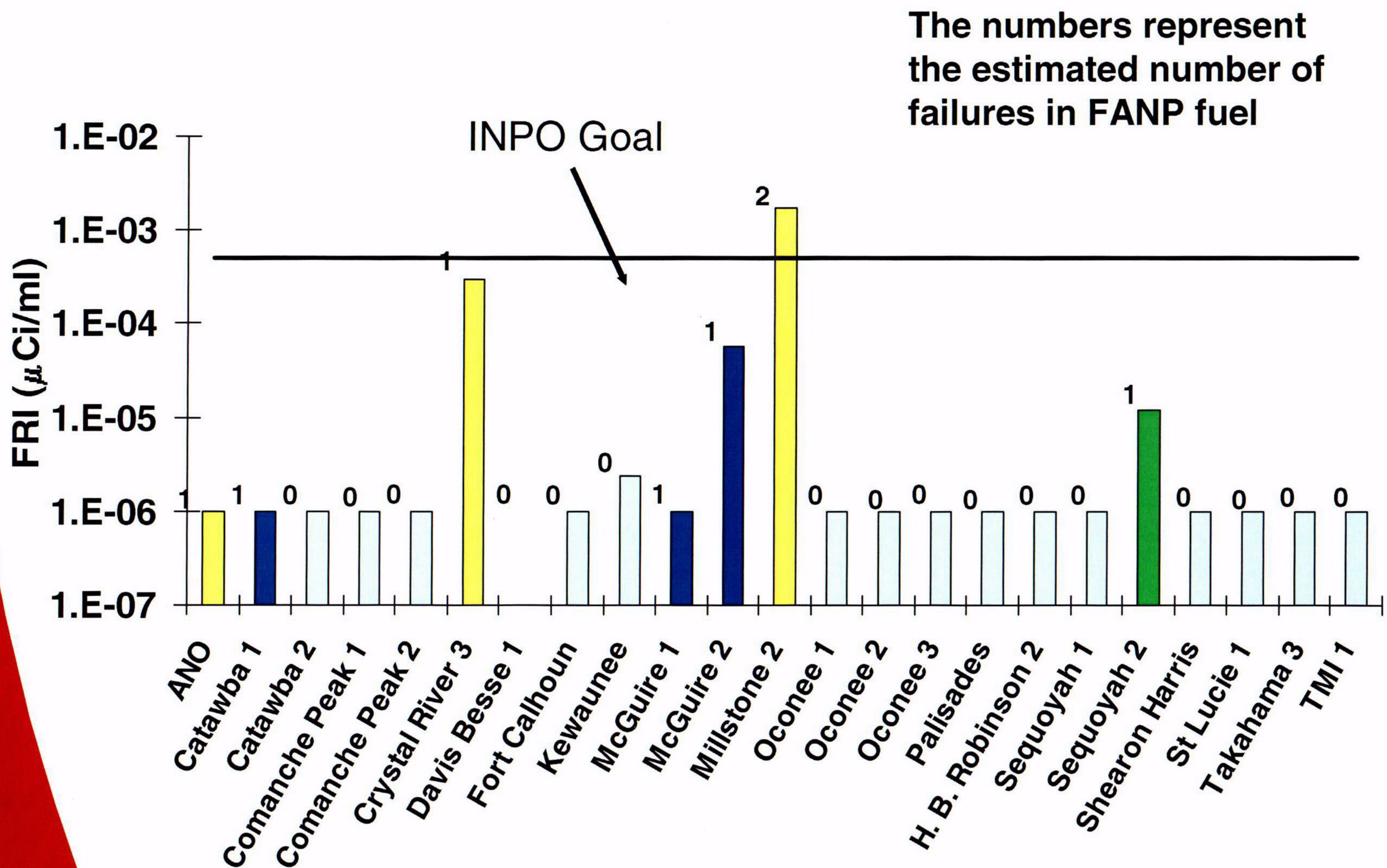
C06

High Burnup Failures

- The plants with the blue bars are plants high burnup, low power failures
- Failures may not be in Framatome ANP fuel, but are considered to be in our fuel for planning purposes
- Cores will be sipped during the refueling outages
- If the failures are in Framatome ANP fuel, root cause failure investigations will be performed
- Refueling outages for these plants start this fall

Framatome ANP PWR Fuel Performance Status



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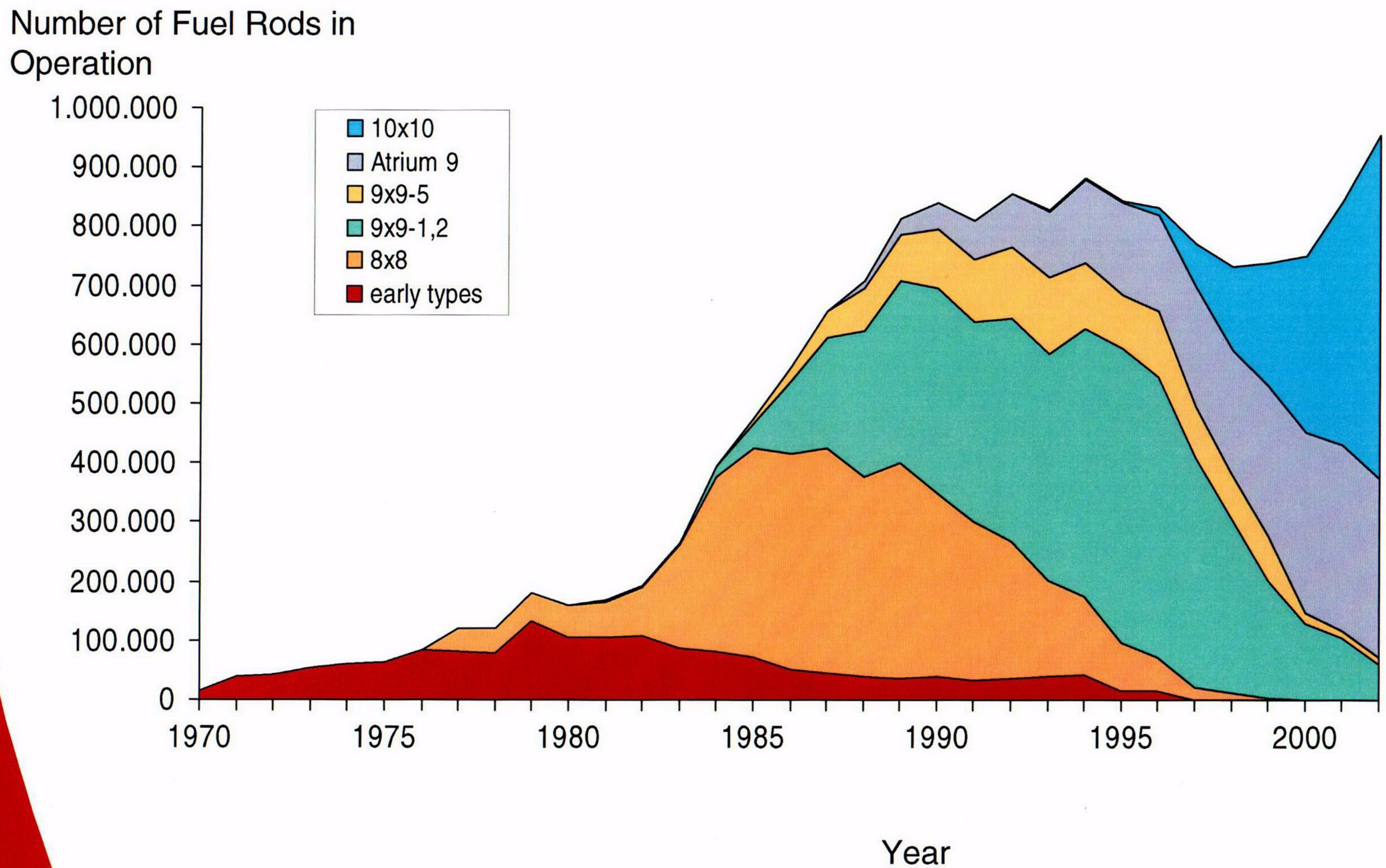
C07

First Cycle PWR Failures

- The plant with the green bar is the only PWR with a first cycle failure
- In the history of the Mark-BW fuel design, there have been only six first cycle failures - four debris failures during transition cycles to the Mk-BW, one failure not examined, and the current failure
- The failure mechanism of the current failure and the previously unexamined failure will be investigated this fall
- First cycle failures are usually either debris or manufacturing related
- Planned changes to the manufacturing process may have already corrected this concern

Framatome ANP BWR Fuel Assemblies
BWR Fuel Types in Operation

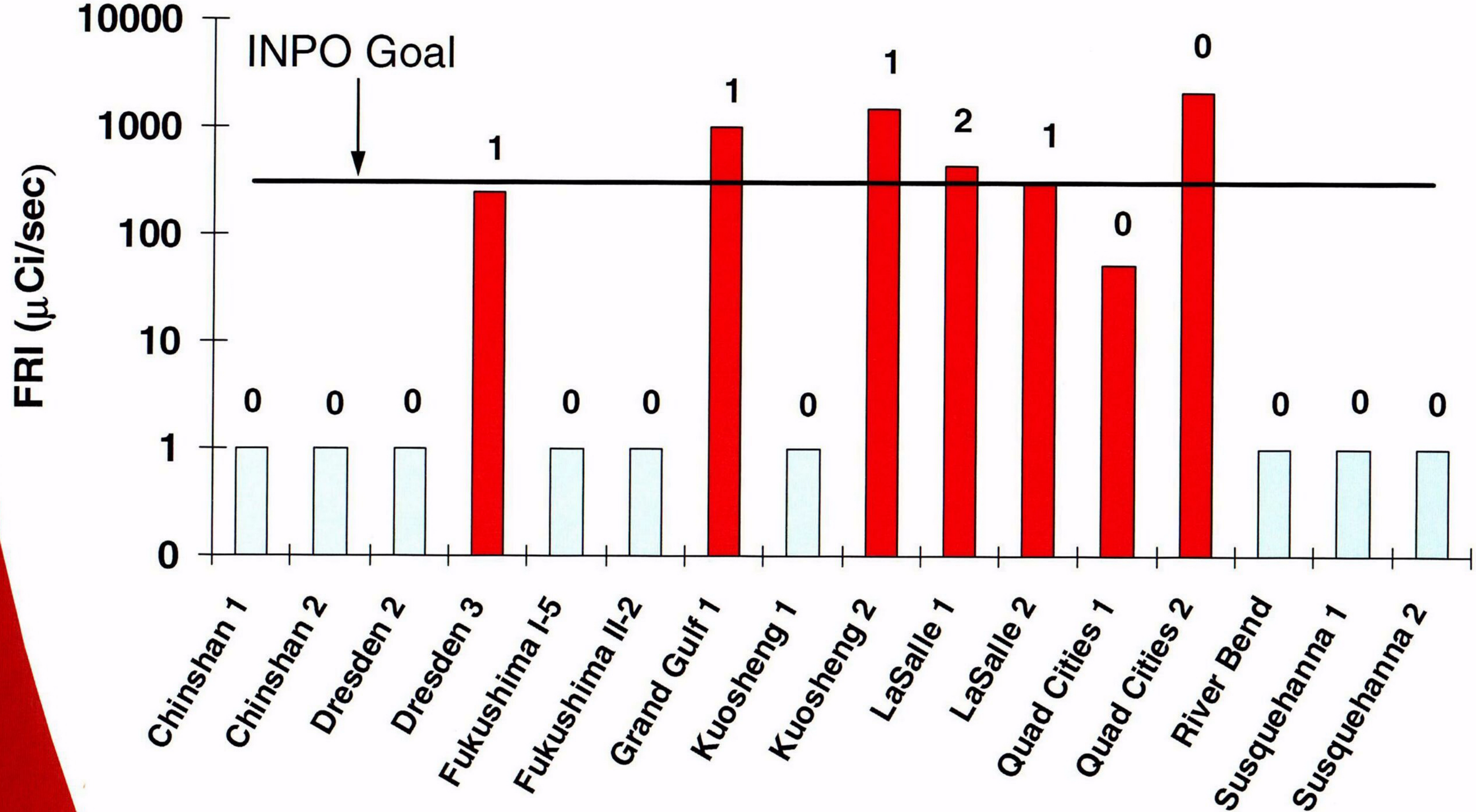


FRAMATOME ANP

C08

Framatome ANP BWR Fuel Performance Status

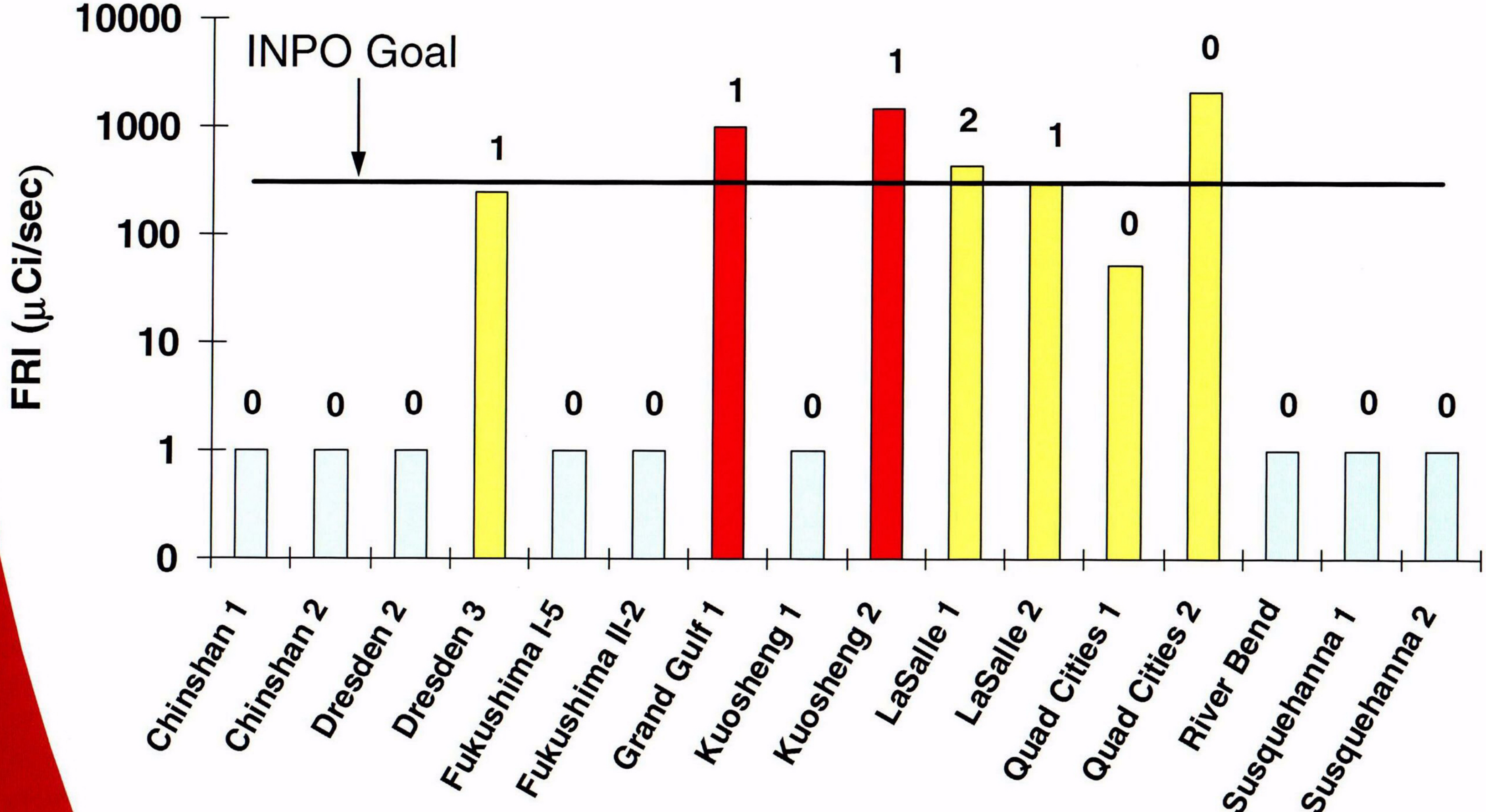
The numbers represents the estimated number of failures in FANP fuel



c09

Framatome ANP BWR Fuel Performance Status

The numbers represents the estimated number of failures in FANP fuel



FRAMATOME ANP

C10

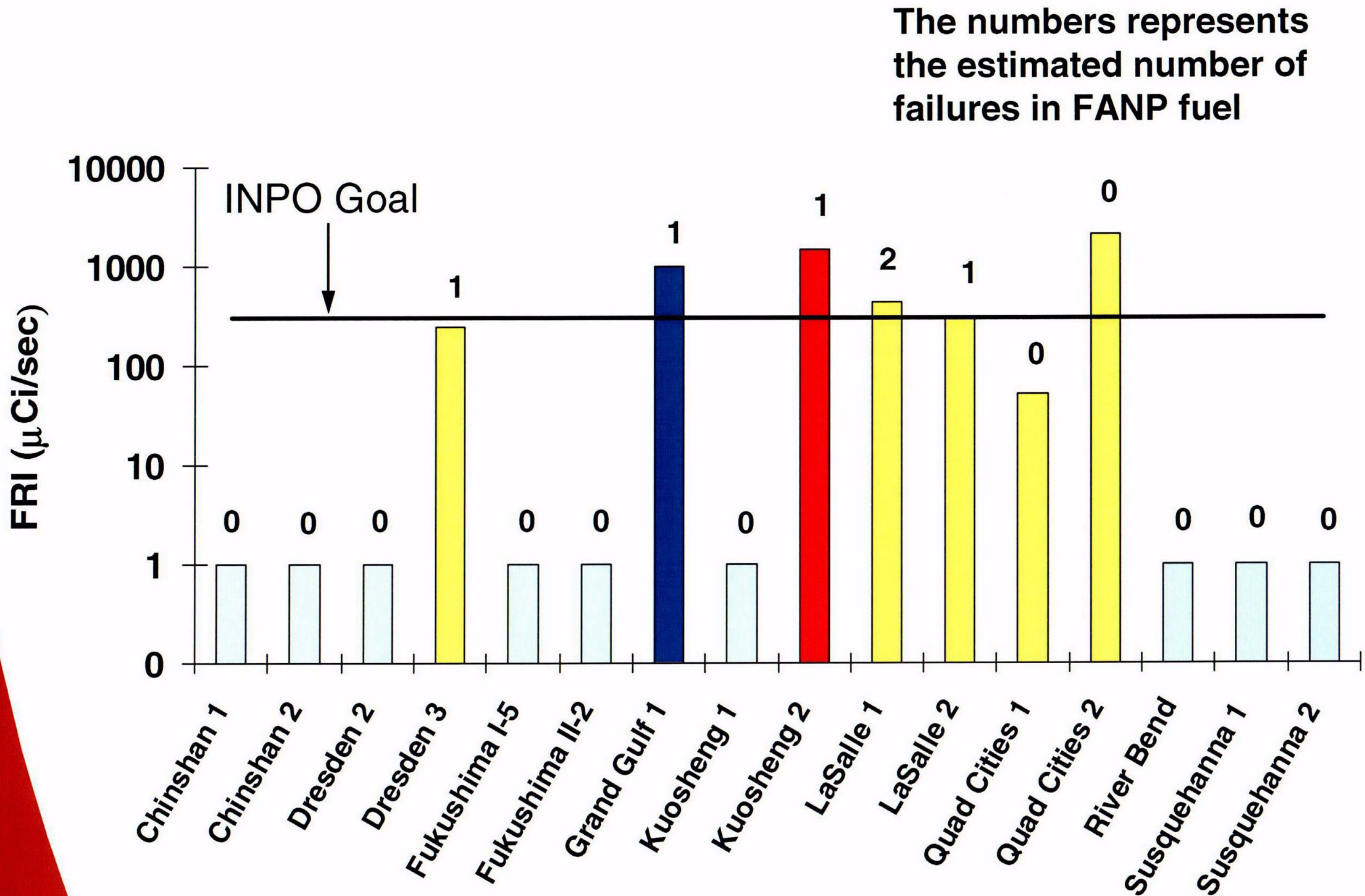
Most BWR Failures Are Associated with a Single Obsolete Design

- The failures in the plants with the yellow bars are believed to be in the ATRIUM-9 fuel design
- These plants are utilizing liner cladding
- Root cause examinations have failed to positively identify the failure mechanism

Most BWR Failures Are Associated with a Single Obsolete Design

- Potential contributors to the failures
  - Hard rod loading (non classical PCI)
  - Long sequence exchanges
  - Deep shallow rod swaps at high power
  - Scram test at high power
  - Zinc injection
  - Noble Metals Chemical Addition
- Hot cell examination is scheduled for this fall

Framatome ANP BWR Fuel Performance Status



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C11

First Cycle BWR Failure

- The plant with the blue bar is believed to contain a first cycle, ATRIUM-10 failure utilizing non-liner cladding
- The failure occurred early in the cycle
- Debris, weld failure, and primary hydriding are the most common failures mechanisms for early in life failures
- The failure will be examined during the next refueling outage at the plant to determine the failure mechanisms

Kuosheng 2

- The failure is believed to be in a second cycle ATRIUM-9 fuel assembly using non-liner cladding
- The failure occurred early its second cycle
- The failure will be examined during the next refueling outage at the plant to determine the failure mechanisms

River Bend

- Six fuel assemblies with failures identified by sipping
- Seven fuel rods identified by UT and/or visual
- Failures were cause by crud induced accelerated corrosion
- Root cause investigation to determine the initiating causes is ongoing
- High zinc, iron, and copper are believed to be contributing factors
- Full flow feed water filters and delayed zinc injection planned for future cycles

Conclusion

- Design and manufacturing process changes have been introduced to eliminate some of the failure mechanisms
- Planned examinations at the site and hot cell to identify the remaining failure mechanisms

Operational Concerns

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Damaged Spacers

- *Spacer grid damage has been eliminated at most plants*
- *Design changes and changes to the handling procedures has minimized spacer grid damaged to the point that spacer grid inspections are no longer required in most plants*
- *One plant continues to damage spacer grids*

Slipped Spacer Grids

- *A design change has eliminated the problem*
- *All fuel assemblies currently in core that are scheduled for additional irradiation include this design change*

Stuck Fuel Assemblies

- *In a few cases utilities have had difficulty inserting a fuel assembly in the core*
- *Problem assemblies have been the last fuel assemblies in a row*
- *Problem is caused by adjacent fuel assemblies bowing into the "hole" which results in higher friction forces*
- *The solution to this problem is the use of a "spreader" tool*

Crud Issues

- **PWR**
  - No problems since TMI Cycle 10 in 1995
  - Work with utilities each cycle to achieve their goals
  - Basically following EPRI Guidelines
  - Zinc addition being performed in 5 to 10 ppb range
- **BWR**
  - Basically following EPRI Guidelines
  - Crud related failures at River Bend in 2003
  - Water chemistry/crud not eliminated as a contributor to the Exelon failures 2002 - hot cell results expected in 2004

Channel Bow

- *No problems encountered to date*
- *Building equipment to measure channel bow and oxide*
- *Campaigns to measure bow are scheduled for early 2004*

Lead Test Assembly Programs

John Strumpell

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Current Programs

▷ Advanced Mark-BW/X1 – North Anna

- **Objectives**
  - Confirm operating performance of design features (MSMGs and Quick Disconnect Top Nozzle)
  - Provide high/extended burnup data on M5™
- **Scope/Status**
  - 3 Cycle LTA program and PIE complete (57 GWd/mtU rod burnup)
  - One assembly reinserted for fourth cycle in North Anna 2
    - PIE - Fall 2004
    - ~71 GWd/mtU fuel rod burnup
    - Potential Hot Cell 2005-2006 (4 cycles)
  - Batch Implementation – Spring 2004

Current Programs

- Alliance 12-foot – Sequoyah 2
  - Objectives
    - Confirm operating performance of design features
    - Additional high burnup data on M5™
  - Scope/Status
    - 4 LTAs complete 1 cycle of operation in April 2002
      - 20 GWd/mtU fuel assembly burnup
    - 4 LTAs currently undergoing 2nd cycle operation (completion scheduled Fall 2003)
      - 42 GWd/mtU fuel assembly burnup
    - PIE 2005 (3 cycles) – Planned rod burnup of 60 GWd/mtu

Current Programs

- ▷ **Alliance 14-foot – Paluel 2**
  - ◆ Objectives
    - Confirm operating performance of design features
    - Additional high burnup data on M5™
  - ◆ Scope/Status
    - 4 LTAs complete 2nd cycle of operation in July 2002
      - 38 GWd/mtU fuel assembly burnup
    - 4 LTAs scheduled to complete 3rd cycle operation October 2003
      - 50 GWd/mtU fuel assembly burnup
    - Final PIE 2006 (5 cycles)
      - 66 GWd/mtU expected fuel assembly burnup

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Current Programs

- M5 High Burnup Fuel Rod – TMI-1
  - Objective
    - Provide extended burnup data on M5™
  - Scope/Status
    - 4 M5 fuel rods
      - Operated for 3 cycles - 48 Gwd/mtU rod burnup
      - Recaged into twice burned fuel assembly
    - Planned burnup of 69 GWd/mtU (4 cycles)
    - PIE – Fall 2003
    - Potential Hot Cell – 2004-2005 (Fourth Cycle)
    - Measure Mark-B12 axial growth pending D-B restart

Current Programs

- **Mark-B10K M5 Structure – Davis-Besse**
  - **Objective**
    - Provide high/extended burnup data on design features
  - **Scope/Status**
    - 4 fuel assemblies up to 52 GWd/mtU rod burnup
      - M5 fuel rods and guide tubes
      - Two uppermost intermediate grids with M5
    - PIE
      - Completed March 2002 (1 cycle) – 28 GWd/mtU rod burnup
      - 2005 (2nd cycle)
      - Potential 2007 @ +62 GWd/mtU

VGB Utility Group
BWR High Burnup Program

Plant	Design	Cladding material	No. of cycles	Rod burnup [MWd/kgU]	No. of (segments)	Main examination
KKP-1	9x9	LTP Fe liner	5	42.2	2 (6)	transient behavior
KKP-1	9x9	LTP Fe liner	8	69.3	2 (6)	transient behavior
KKP-1	10x10	LTP Fe liner	5	57.3	2 (6)	transient behavior shadow corrosion
GUN-B	10x10	LTP Zr liner	8	64.5-73.4	21	fission gas release, shadow corroosion
KKK	9x9	LTP Zr liner	8	67.3-69.9	2	fuel and cladding behavior

GUN-B High Burnup Program

- *Objective:*
  - *Burnup 70 MWd/kgU*
  - *ATRIUM™-10A design*
- *Description:*
  - *4.95 % max. U235 enrichment*
  - *Advanced pellets, cladding and spacer materials*
- *Scope:*
  - *Begin irradiation, 1999: 8 FA*
    2000: 4 FA (large grain fuel)
  - *Intermediate pool site examinations after 2, 4, 6 and 7 cycles*
  - *Final pool site and hot cell examinations after 5 and 8 cycles*
- *Status:*
  - *Intermediate exam performed at 26 GWD/tU*

Description of Recent Post-Irradiation Examinations

PWRs

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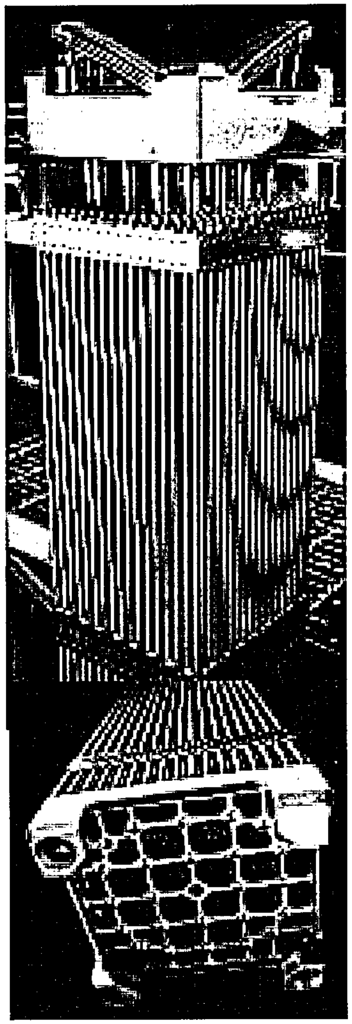
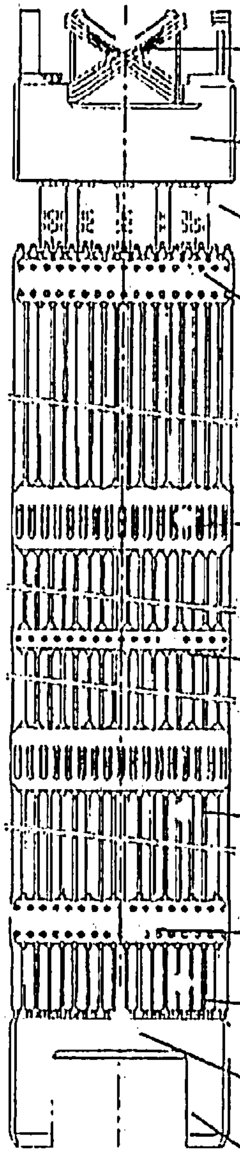
alliance™




Holddown springs
Quick disconnect top nozzle
Large top nozzle - fuel rod gap
Bi-metallic (M5 / Inconel) top grid
Mono-metallic grid (M5)
Mid span mixing grid * M5 (* optional)
Fuel rod with M5 cladding
Bi-metallic (M5 / Inconel) bottom grid
MONOBLOC™ guide thimble (M5)
Seated fuel rods
TRAPPER™ anti-debris nozzle

PIE Objectives

- *Continue confirmation of advanced designs and materials*
- *Purpose of the latest PIE data is to specifically support:*
  - *High burnup*
  - *M5™*
  - *Mark-B11 design*
  - *Advanced Mark-BW design*
  - *Alliance design*
  - *CE Design with M5 Clad*
  - *Mark-B-HTP*

Post Irradiation Exams - Preliminary

- **Recently Completed**
  - Paluel 2, Cycle 13 – Alliance 14 ft LTAs
  - Oconee 3, Cycle 20 – Mark-B11 Batch
- **Upcoming**
  - Sequoyah 2, Cycle 12 – Alliance LTAs
  - TMI, Cycle 14 - Mark-B12 Batch
  - Paluel 2, Cycle 14 – Alliance 14ft LTAs
  - Oconee 1 - Mark-B11
  - North Anna 2, Cycle 15 – Advanced BW

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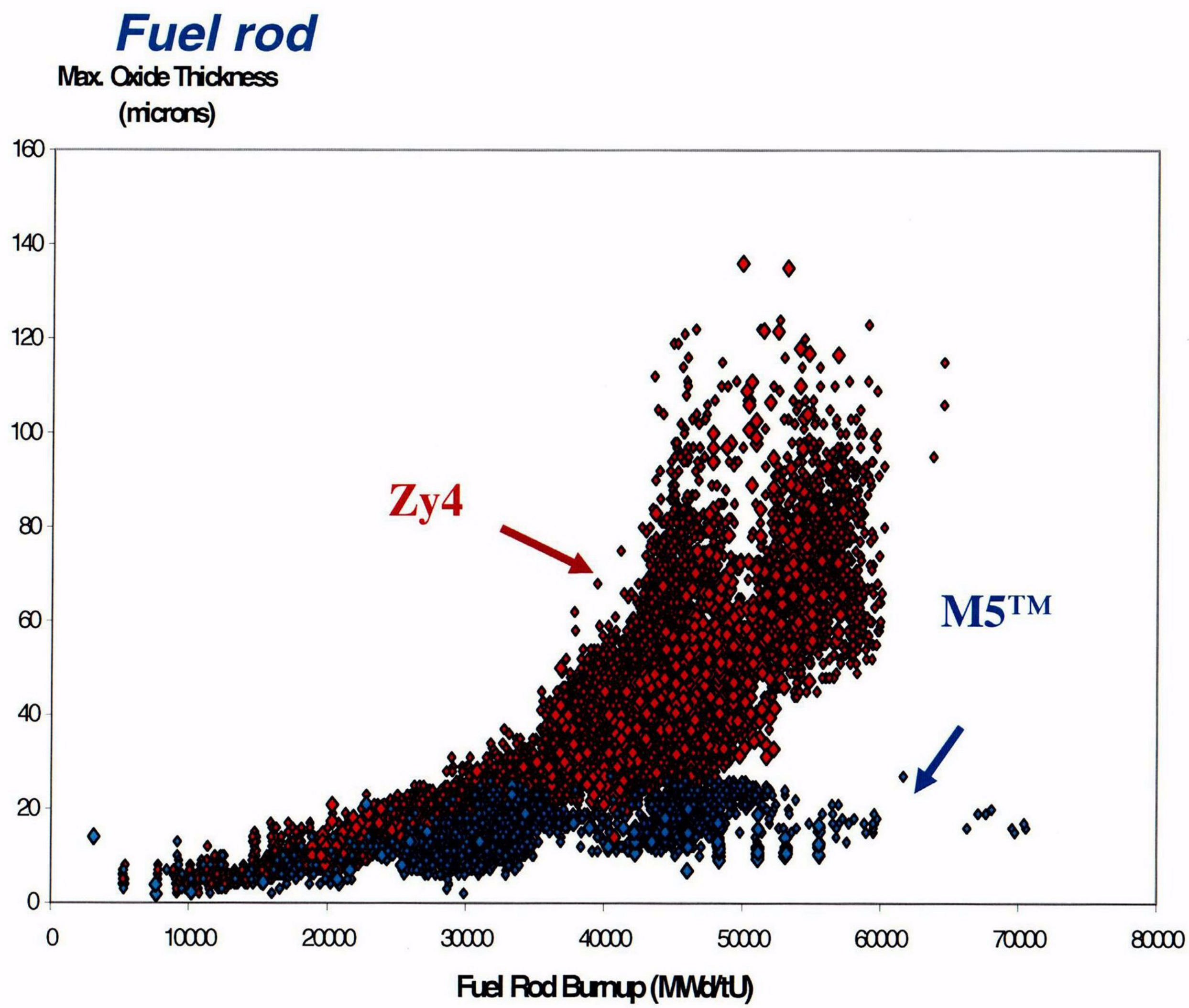
North Anna PIE

- 2004: 4th Cycle PIE on North Anna LTA (preliminary)
  - Oxide measurements
    - Fuel rod (4 rods/face, second span from top)
    - Guide tube (4 GTs, full length)
    - Grid (4 grids, 6 measurements/grid)
  - Fuel assembly
    - Water channel (7 spans, 2 lateral directions)
    - Bow (2 orthogonal sides)
    - Growth (4 GTs); grid position if time permits
  - Fuel rod
    - Shoulder Gap – captures growth (typically 16-20 rods/FA + 2 longest rods per visual exam)

M5™ Exhibits the Best Corrosion Behavior in PWR



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C12

M5™ Fuel Rod Growth

- *U.S and worldwide M5™ fuel rod growth data are consistent*

[ ]

North Anna Advanced MK-BW LTAs Show No Growth

[

]

Mark-B10 (15x15) Fuel Assembly Growth Experience

[ ]

Raised Rod PWR Fuel Assembly Growth

[ ]

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PWR Guide Bar Assembly Growth

[ ]

Water Channel Worst Case Closure vs. Burnup

Grid Growth – Slightly Below Zr-4 Levels

[ ]

M5 Summary

- Corrosion well behaved at high burnup
- Fuel Rod Growth
  - Zirc-4 fuel assembly and fuel rod growth supports existing models
  - M5™ fuel rod growth supports existing M5™ model
    - U.S. data is consistent with worldwide data
    - Rod growth saturates above 40 GWd/mtU
- Fuel Assembly Growth
  - Advanced Mark-BW M5™ fuel assembly growth is low
  - Mark-B M5™ fuel assembly growth follows zirc-4 growth for low burnups as expected and should saturate above 40 GWd/mtU
  - Dependant on structure
  - Currently using conservative design limits based on PIE data
- Water channel gap within existing limits
- Grid growth slightly below Zr-4 levels below 40 GWd/mtU

Description of Recent Post-Irradiation Examinations

BWRs

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Long-Term PIE Goals

- *Continued confirmation of existing and advanced designs*
- *Provide data to validate new designs to burnups above current levels*
- *Information to support future robust fuel data needs*
  - *Selective assemblies for 3rd and 4th cycle burnups > 65 GWd/mtU*
  - *Selective reconstitution of M5™ fuel rods to reach rod burnups of 70-75 GWd/mtU*

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Recent U.S. and Important German BWR Exams

Reactor	Main evaluation
▷ Gundremmingen B	Oxide, growth, hot cell
▷ Susquehanna	Oxide, growth, creepdown
▷ Dresden	Oxide/CRUD

BWR Cladding and Structural Materials

- ATRIUM-10 Inspection Results
- Shadow Corrosion

Corrosion of Fuel Rods with LTP Cladding

[ ]

Diameter Change of Fuel Rods with LTP Cladding

[ ]

Corrosion of BWR Structural Components Made of Zry-4 and Zry-2

[ ]

Shadow Corrosion Caused by All-Inconel Spacer Grids on Neighboring Components

- Comparative single rod measurements of two fuel rods each with identical burnup after 5 irradiation cycles

  (FR burnup 58 MWd/kgU):

  ATRIUM-10P: All-Inconel spacer

  ATRIUM-10B: Zry spacer with Inconel springs

- Oxide measurement inside a fuel channel opposite to all-Inconel spacers

Shadow Corrosion on Fuel Rods

(Comparison of all-Inconel SG to Zry spacer with Inconel springs)

Shadow Corrosion: Summary

- *The extent of Shadow Corrosion is influenced by the plant and the Zr material-type*
- *Extent of Shadow Corrosion caused by an all-Inconel spacer comparable to that caused by Inconel spacer springs*

Dresden Crud/Oxide Measurement

- 2 assemblies, 3 cycles to 38 GWD/tU
  - One reference
  - One operated 3rd cycle in NMCA
- Rods, 12 measured
  - Dual frequency corrosion thickness measurement
  - Crud scrapes
- Preliminary results
  - Measurement system appears reliable
  - Total thickness increase seen under NMCA

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ATRIUM™ -10 Global Inspection Program

Reactor	FA Type	93	94	95	96	97	98	99	00	01	02	03	04
GUN–B	10A liner	1	2	3□	4◇	5◇	5◇	6◇	7□	8□H			
	10A non–liner					1v	2v	3v	4	5v	6□		
KKL	10B liner						1v	2v	3□	4□	5v	6□H	
TVO–1	10B non–liner				1v	2v	3□	4□					
	10B liner							1v	2v	3v	4□	5□	6v
TVO–2	10B non–liner				1v	2v	3□	4					
BRA	10B non–liner					1v	2	3v					
OKG–2	10B non–liner							1	2v	3	4	5	
OKG–3	10B non–liner					1	2	3v	4v		5v		
FMK–1	10B non–liner					1v	2	3	4				
FMK–3	10B liner							1	2v	3	4□	5	6
RH–1	10B liner							1v	2□	3	4□	5	6
KKP–1	10B/10P liner					1v	2◇	3◇	4□	5□H			
GUN–C	10–8 liner		1◇	2◇	3□	4◇	5◇	6□					

v Visual Inspection ◇ Visual + Length □ Visual, Lenght, FR Oxide+Diam. (outer row)

□ Visual, Length, FR Oxide+Diam., WC Oxide+Dimensions H Hot Cell Examination

Preliminary Examination Schedule

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ATRIUM™ -10 Fuel Assemblies in GUN-B

- First time a BWR assembly reached 71 MWd/kgU with maximum rod burnup of 73.4 MWd/kgU
- The fuel assemblies, fuel rods and channels showed good behavior
- Fuel channels made of Zry-4 show a corrosion acceleration at high burnup
- Detailed hot cell examination will be performed in addition to the final pool examination

ATRIUM™-10 Fuel Assembly Growth (German Region)

[ ]

ATRIUM™ -10 Assembly Growth (U.S. Region Data)(Comparison with Fuel Channel Growth)

[ ]

ATRIUM™ -10 Rod Growth (CWSR Clad) (Compared with Other Arrays)

[ ]

Summary

- ***High burnup fuel rods and demonstration assemblies equipped with advanced materials are continuously monitored by pool site inspections and hot cell examinations***
- ***Such examinations verify the material behavior of burnups beyond present limitations and provide data for model calibration***

Update on Performance of Framatome-Supplied PWR/BWR Fuel

U.S. High Burnup Programs and Status

John Willse

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U.S. High Burnup Support Activities

- Participate in all phases of Robust Fuel Program
- Obtain required poolside and hot cell data for rod burnups above current limits to support future utility requirements
  - For BWR applications, integrate German Region experience
  - For PWR applications, focus on M5™ clad and structure experience
    - French Region data
    - North Anna LTAs
    - TMI M5™ fuel rods
    - Alliance™ LTAs
    - Davis Besse M5™ structure FAs

Robust Fuel Program Focus

- *Resolve existing operation and reliability problems*
  - *AOA and crud deposit (WG 1)*
  - *Water chemistry related (area of increasing concern) (WG 1,4)*
  - *Failure root cause investigations (WG 4)*
    - *LaSalle Hot Cell Exam (joint RFP/FANP)*
- *Reduce regulatory burden (WG 2)*
  - *Burnup extension, RIA & LOCA*
    - *NRC review of RIA criteria topical expected to take > 2 years from April 2002*
    - *Submittal of HBLG anticipated late 2003 – LOCA criteria still an issue*
- *Ensure margins under high duty conditions (WG 3/4)*
  - *FANP North Anna poolside measurements:*
    - *3rd cycle completed 2002*
    - *4th cycle poolside and hot cell discussions in progress for 2004-2005*
  - *BWR Channel Bow – FANP developing advanced measurement system*

European Data on High Burnup M5™

- 2002 - Hot cell examinations of M5™ at 71 GWd/mtU
- 2002 - M5™ poolside examinations at 55 GWd/mtU (2 long high duty cycles)
- 2004 (January) - M5™ poolside examinations at 78 GWd/mtU (7 cycles)
  - Hot cell (2003/2004) examinations planned for both
- 2002 - Alliance™ LTAs (14') poolside examination at ~30 GWd/mtU (second cycle)
- 2004 - Alliance™ LTAs (14') poolside examination at ~45 GWd/mtU (third cycle)
- 2006 - M5™ poolside examinations at 70 GWd/mtU (5 cycles)

European Data on High Burnup M5™

- **Poolside Exams**
  - 1999 - 12 five cycle rods – peak rod 58 GWd/mtU
  - 2001 - 4 six cycle rods – peak rod 68 GWd/mtU
    - 3 five cycle rods – peak rod 57 GWd/mtU
  - 2004 - 3 six cycle rods – peak rod 69 GWd/mtU
    - 4 seven cycle rods – peak rod 78 GWd/mtU
- **Hot Cell Exams**
  - 1999 - 4 five cycle rods from 52 to 58 GWd/mtU
  - 2001 - 7 rods from 54 to 68 GWd/mtU
  - 2004 - 7 rods from 64 to 78 GWd/mtU

Summary Of European Data on High Burnup on M5™ that will have been examined by 2004

- 510 fuel rods at a burnup of greater than 60 GWd/mtU will have been examined poolside
- 12 fuel rods at a burnup of greater than 60 GWd/mtU will have been examined in hot cells

North Anna LTAs

- *Poolside exam after 3rd cycle at peak rod burnup of 56 GWd/mtU (January 2002)*
  - *EPRI/RFP sponsored*
  - *Excellent results - low oxide and growth*
- *4th cycle irradiation*
  - *Licensing submittals approved by NRC in 2002*
  - *Irradiation in North Anna 2 Cycle 16, started in January 2003, due to delay for head replacement*
- *Poolside and hot cell exams on fuel rod and guide tube from 4th cycle ~70 GWd/mtU (2004 - 2005) being planned*

M5™ Fuel Rods at TMI-1

- Four M5™ fuel rods were licensed and reinserted for a fourth 2-year cycle in October 2001 (BWOG sponsored)
- Planned poolside exam after 4th cycle with peak rod ~ 69 GWd/mtU (early 2004) (BWOG and possibly NEPO sponsored)
- Potential hot cell exam of 4th cycle rod (2004 - 2005) under consideration

Alliance™ 12-foot LTAs in Sequoyah 2

- Poolside exam completed after 1st cycle (April 2002)
  - Peak rod burnup of 25 GWd/mtU
  - Growth as expected, similar to North Anna LTAs
- Planned poolside exam after 2nd cycle (Fall 2003)
- Planned poolside exam after 3rd cycle $\geq$60 GWd/mtU peak rod (2005)

Davis-Besse M5™ Structure LAs

- *First 2-year cycle completed, peak rod burnup of ~28 GWd/mtU*
- *Poolside exam indicates growth within allowable limits for first cycle operation*
- *Expect peak rod burnup of ~54 GWd/mtU after second 2-year cycle (Fall 2005 or Spring 2006?)*

Conclusion

- *Robust Fuel Program activities, including high burnup licensing guide development, are being fully supported*
- *North Anna LTA 4th cycle started January 2003*
- *M5™ fuel rods at TMI-1 will complete a 4th 2-year cycle in Fall 2003*
- *Alliance™ LTAs will be examined in Fall 2003 after their 2nd cycle of operation*
- *Data collection and model development are on schedule to support utility requirement to increase fuel rod burnup limit to 75 GWd/mtU*