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Fuel Performance Meeting

April 8-9, 2008

Lynchburg, VA

AREVA NP Inc.

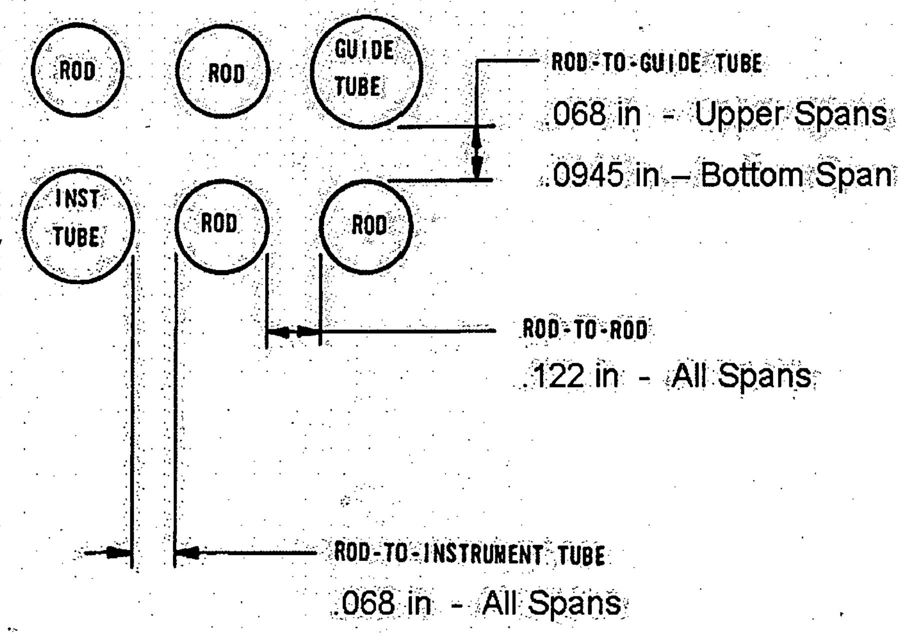
Meeting Agenda

> Introductions
> NRC Notification – Letter Objectives
  - Describe events and current status
    - Description of occurrence of fuel rod bow at North Anna
    - Definition of actions taken
  - Provide Apparent Cause Analysis overview
    - Technical and programmatic causal factors
    - Extent of condition
  - Provide overview of governing topical
  - Discuss potential problem (difference between occurrence and topical)
  - Action Plan Overview/Status
> Preliminary water channel measurements – North Anna 1
> Summary
> Q&A

Description of Fuel Rod Bow Occurrence History of Events

Rod Bow

> *Alters design pitch dimensions, or water channel gap, between adjacent rods within a Advanced Mark-BW fuel assembly array which affects:*

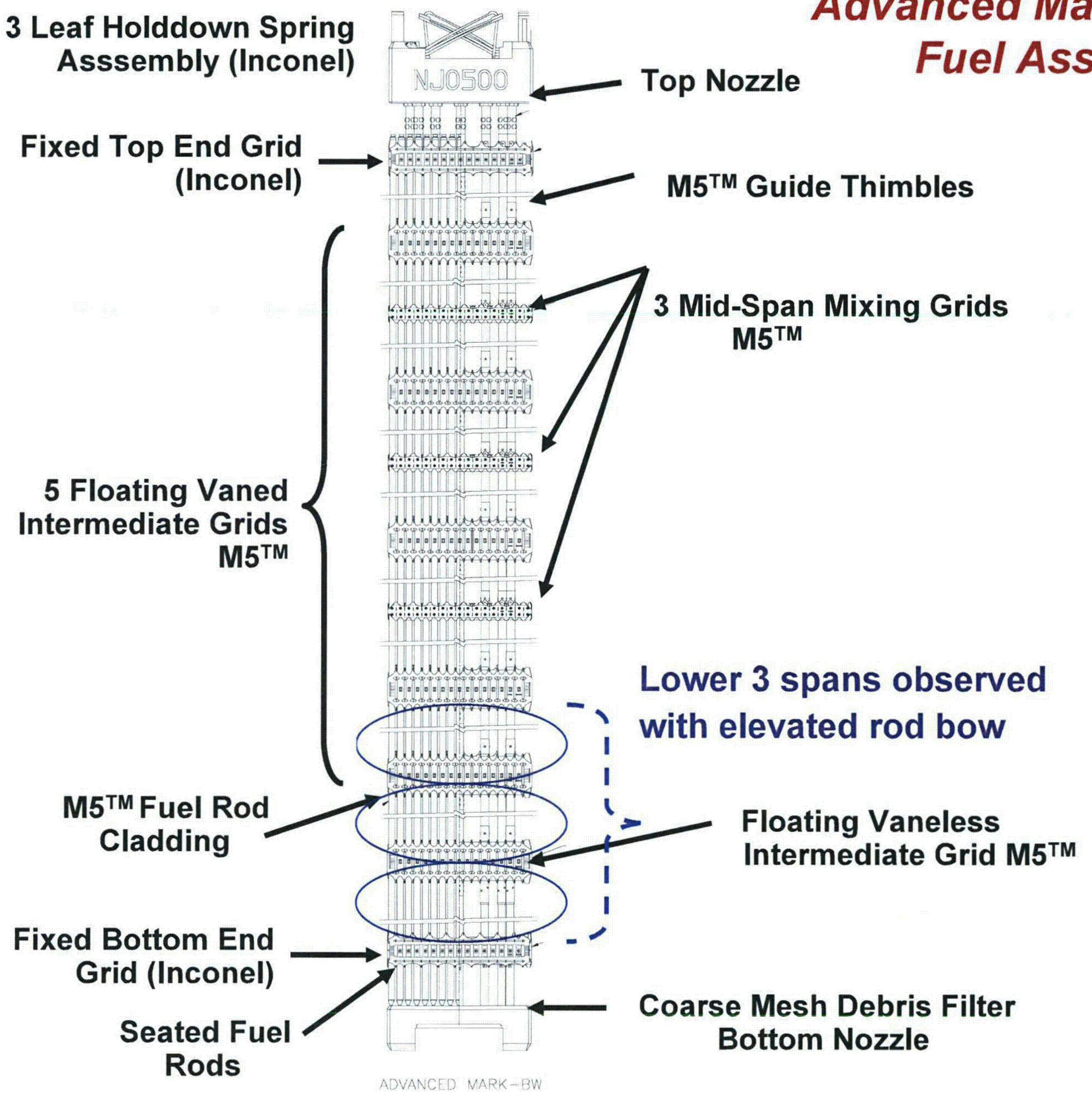


- *Local nuclear power peaking*
- *Local heat transfer to coolant*

> ***Consequence*** ➔ *local excessive over-heating of fuel rod cladding which may lead to failure*

Rod Bow Occurrence

Advanced Mark-BW Fuel Assembly



North Anna Unit 2 EOC 18 Fuel Rod Bow

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Actions Taken

Actions Taken (cont.)

> *Actions taken following North Anna Unit 1 observations*

[ ]

Actions Taken (cont.)

- Actions taken following North Anna Unit 1 observations
  - Completed Deviation Determination
    - Event classified as a deviation; observed performance not expected.
  - Defect Determination completed
    - Determined not a Defect as the condition does not create a substantial safety hazard.
      - Fuel system integrity is preserved during normal operation and would be during anticipated operational occurrences (AOOs),
      - Operation at Rated Thermal Power will not cause the core safety limits to be exceeded,
      - Fuel system integrity to facilitate control rod insertion when required is preserved,
      - The number of fuel rod failures is within the design for postulated accidents, and fuel coolability is always maintained.
      - Current technical specifications related to safety limits continue to be supported with the observed and expected bow.

Apparent Cause Analysis Findings

Apparent Cause

Grid Cell Size Change Due To End Grid Supplier/Process Change

Mt Athos Road and NFI Supplied End Grids

> Pronounced reduction in grid cell size and increase in variability

> ~35% increase in corner and periphery cell slip loads

> ~20% increase in slip loads due to M5

Rod Bow - Extent of Condition

Rod Bow - Extent of Condition

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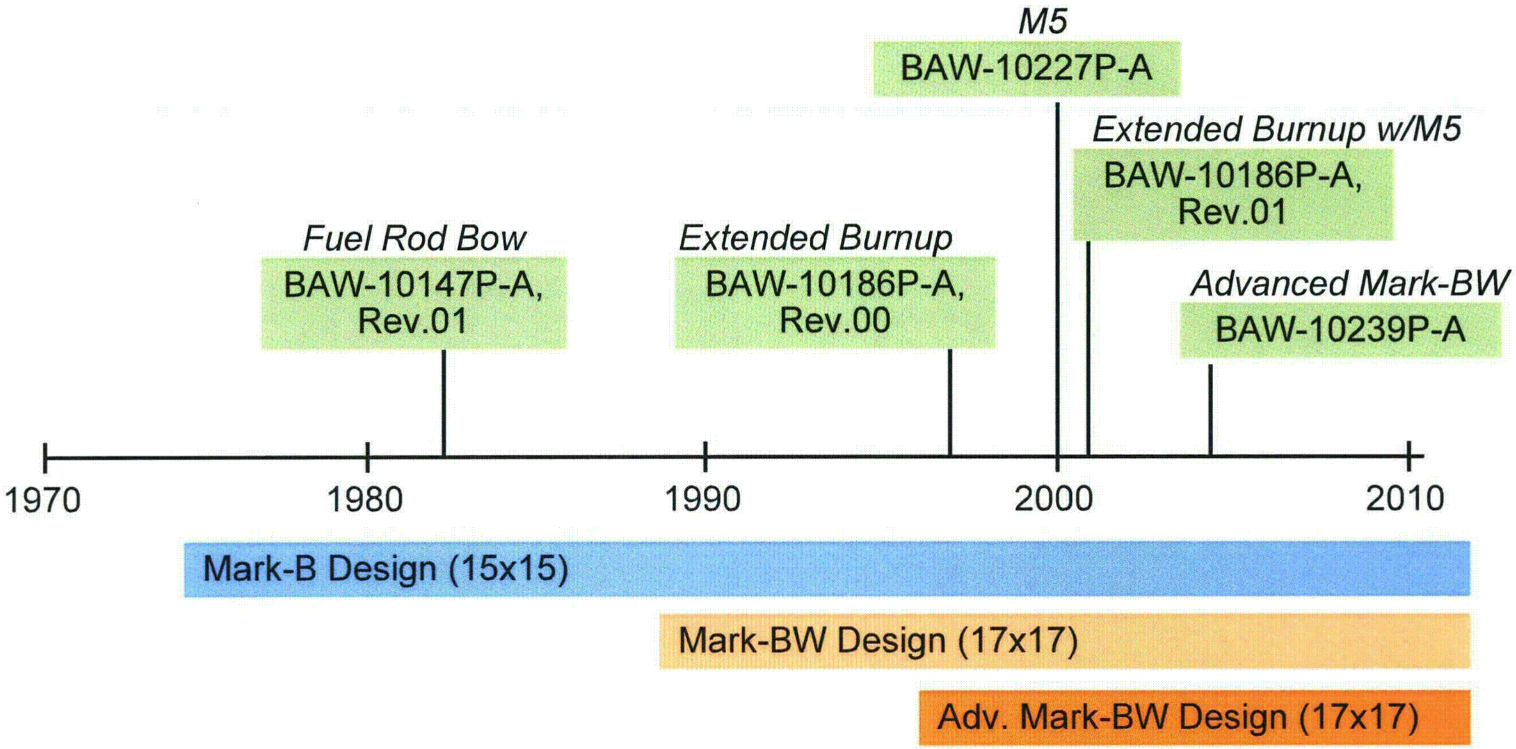
Governing Rod Bow Topical and Methodology

AREVA Topical Report and Fuel Design Timeline



Fuel Rod Bow Topical Reports and SERs

> BAW-10147P-A, Rev.01, Fuel Rod Bowing in Babcock & Wilcox Fuel Designs, May 1983.

[ ]

Fuel Rod Bow Topical Reports and SERs (cont.)

> BAW-10147P-A, Rev.01, Fuel Rod Bowing in Babcock & Wilcox Fuel Designs, May 1983.

[ ]

Fuel Rod Bow Topical Reports and SERs (cont.)

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> - *BAW-10147P-A, Rev.01, Fuel Rod Bowing in Babcock & Wilcox Fuel Designs, May 1983.*

Fuel Rod Bow Topical Reports and SERs (cont.)

> BAW-10147P-A, Rev.01, Fuel Rod Bowing in Babcock & Wilcox Fuel Designs, May 1983.

[ ]

Fuel Rod Bow Topical Reports and SERs (cont.)

> *BAW-10186P-A, Rev. 00, Extended Burnup Evaluation, June 1997.*

Fuel Rod Bow Topical Reports and SERs (cont.)

Measured Water Channel Gap Data (Worst Span)

Description of Potential Issue

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Potential Issue

Application of Methodology

Rod Bow Summary

Action Plan Overview / Status

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Action Plan Overview / Status

Action Plan Overview / Status (cont.)

Action Plan Overview / Status (cont.)

Action Plan Overview / Status (cont.)

Water Channel Measurements North Anna 1

North Anna 1 Water Channel Measurements

> Scope
- 8 Advanced Mark-BW fuel assemblies
- Bottom 3 spans – 2 faces minimum

> Status
- 6 fuel assemblies measured

> Preliminary Results
- Well below 95/95 UTL of BAW-10147P-A Rev 01
- Worst span water channel standard deviations near or slightly above observed limit of BAW-10186P-A Rev 00

Preliminary North Anna Advanced Mark-BW Water Channel Data

Preliminary North Anna Advanced Mark-BW Water Channel Data

Preliminary North Anna Advanced Mark-BW Water Channel Data (cont.)

Fuel Rod Bow Presentation Summary

Summary

> AREVA continues to apply the methodology defined in BAW-10147P-A Rev 01 for the Advanced Mark-BW fuel

> Preliminary data indicate that the Advanced Mark-BW fuel is operating within the 95% tolerance limit (BAW-10147P-A Rev 01)

> AREVA is committed to understanding fuel rod bow behavior and implementing the necessary improvements to recover margin and improve performance

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Q&A
Open Discussion

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Fuel Performance Meeting

April 8-9, 2008

Lynchburg, VA

AREVA NP Inc.

Fuel Performance Meeting
April 9, 2008

> 8:00 Welcome – Gardner
  - Introduction and Purpose
  - Description of AREVA NP Inc.
  - Plans for Future Topical Reports

> 8:30 BWR Fuel Designs and Methods – N. Garner
  - Description of Current Fuel Designs
  - New Fuel Designs and Methods

> 9:45 Break

> 10:00 PWR Fuel Designs and Methods – Uyeda/Lotz
  - Description of Current Fuel Designs
  - New Fuel Designs and Methods

> 11:30 Lunch

> 12:30 Recent Fuel Performance Experience – Willse

> 1:30 BWR Fuel and Hardware Testing Programs – Montgomery

> 2:00 Fuel Channel Performance - Smith

> 3:00 Break

> 3:15 PWR Fuel and Hardware Testing Programs – Montgomery

> 4:00 M5 Experience Summary – Montgomery

> 5:00 Conclusion - Gardner

Introduction and Purpose

Ronnie L. Gardner
Manager, Site Operations &
Corporate Regulatory Affairs

Introduction

- Introduction of participants
- Outline of discussion
  - Current fuel designs
  - New fuel designs and methods
  - Recent experience
  - Fuel development
- Objectives
  - Understanding AREVA NP Inc.'s fuel design
  - Exchanging ideas and expectations on fuel issues
  - Open communication; ask questions

Description of AREVA NP Inc.

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AREVA NP Inc. Executive Team

Tom Christopher
President and CEO

George Beam
Sr. Vice President
Nuclear Services

Joe Zwetolitz
Vice President
Fuel America

Tom Franch
Sr. Vice President
Nuclear Eng. and
New Plants Eng.

Tony Granda
Sr. Vice President
Equipment & IC&E

Ray Ganthner
Sr. Vice President
New Plants
Deployment

John Matheson
Sr. Vice President
Projects Group

Andrew Cook
Sr. Vice President
Sales & Marketing

Steve Hamilton
Vice President
AREVA NP CN, Ltd.

Tom Stevens
Sr. Vice President
Federal Group

Bob Williams
Vice President &
CFO

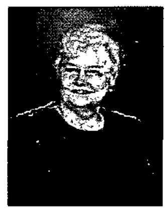
David Guza
Chief Counsel
Legal

Kevin McHenry
Director
Purchasing

Jim Hicks
Vice President
Business Integration

Steve Blickenstaff
Vice President
HR & Facilities

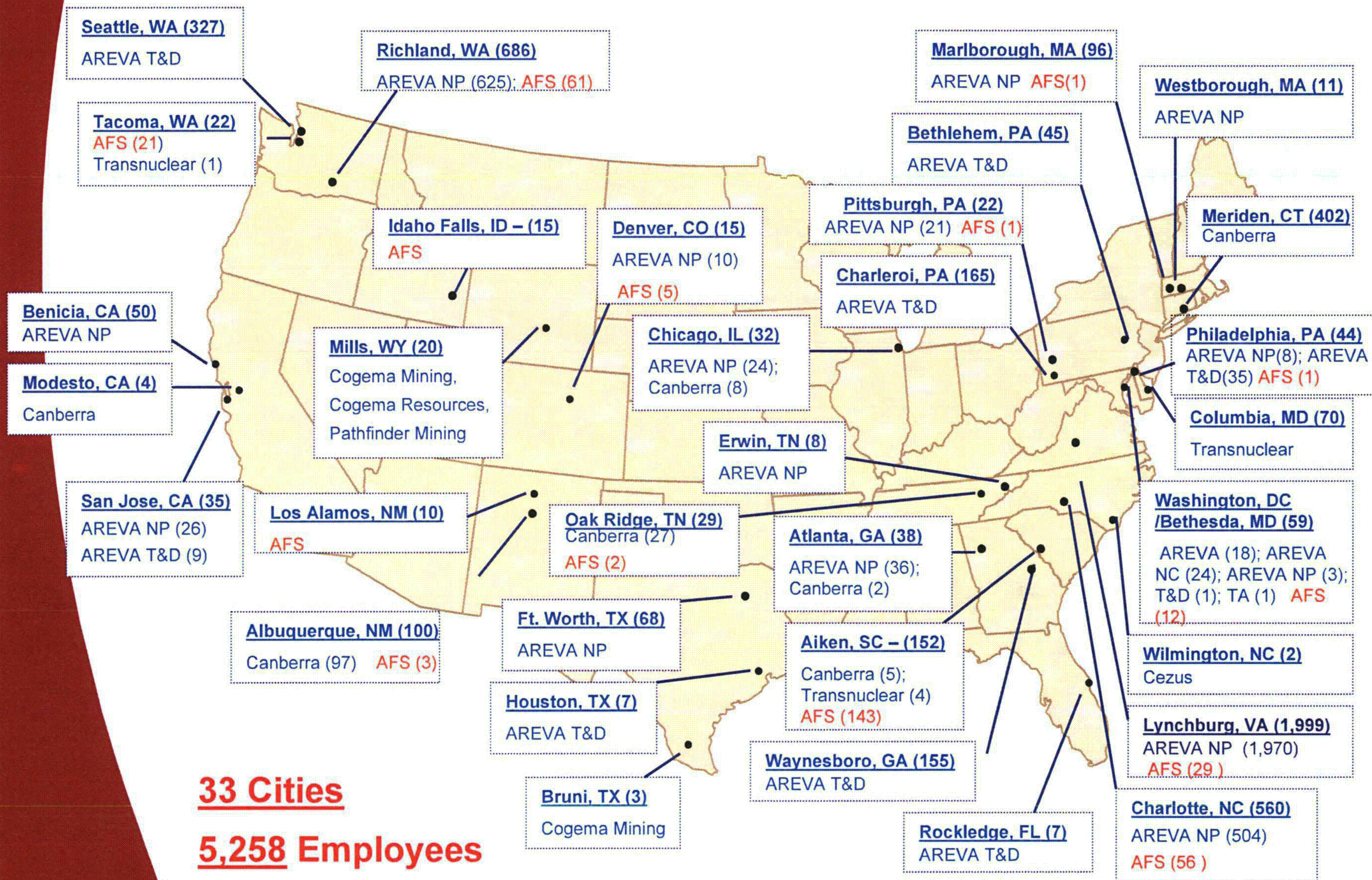
Bob Kibler
Vice President
Information Systems



Emily Mayhew
Vice President
Region Quality

Bill Fox
Vice President
Charlotte Site &
U.S. Region Safety

US Locations – March 2008



33 Cities

5,258 Employees

AREVA

> World leader in the energy business

- N°1 in the entire nuclear cycle
- N°3 in electricity transmission and distribution

> Our mission

- Enabling everyone to have access to ever cleaner, safer and more economical energy

> Our strategy

- To set the standard in CO_2-free power generation and electricity transmission and distribution
  - Capitalize on our integrated business model to spearhead the nuclear revival:
    - Build one third of new nuclear generating capacities
    - Make the fuel secure for our current and future customers
  - Ensure strong and profitable growth in T&D
  - Expand our renewable energies offering.

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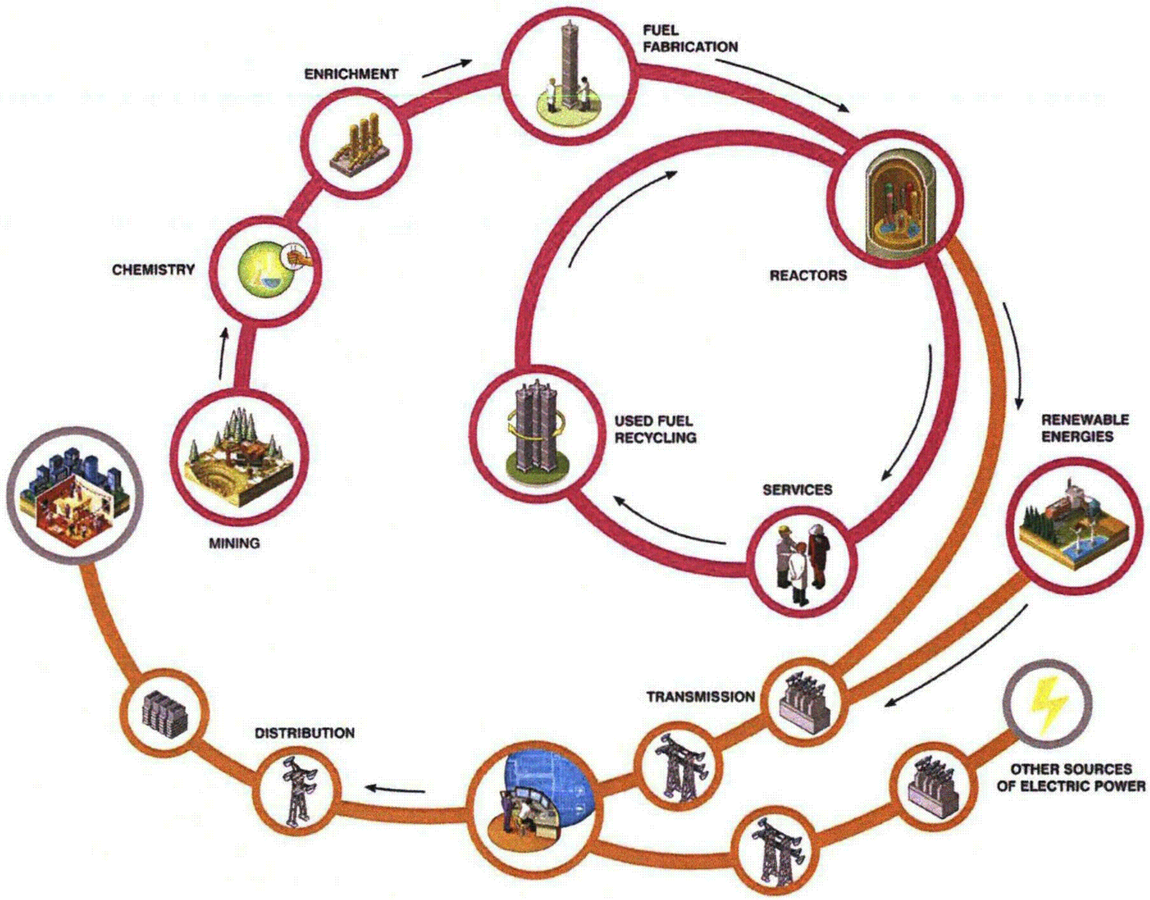
CO_2- free power generation solutions



Nuclear

Transmission & Distribution

Solutions for reliable electricity transmission and distribution

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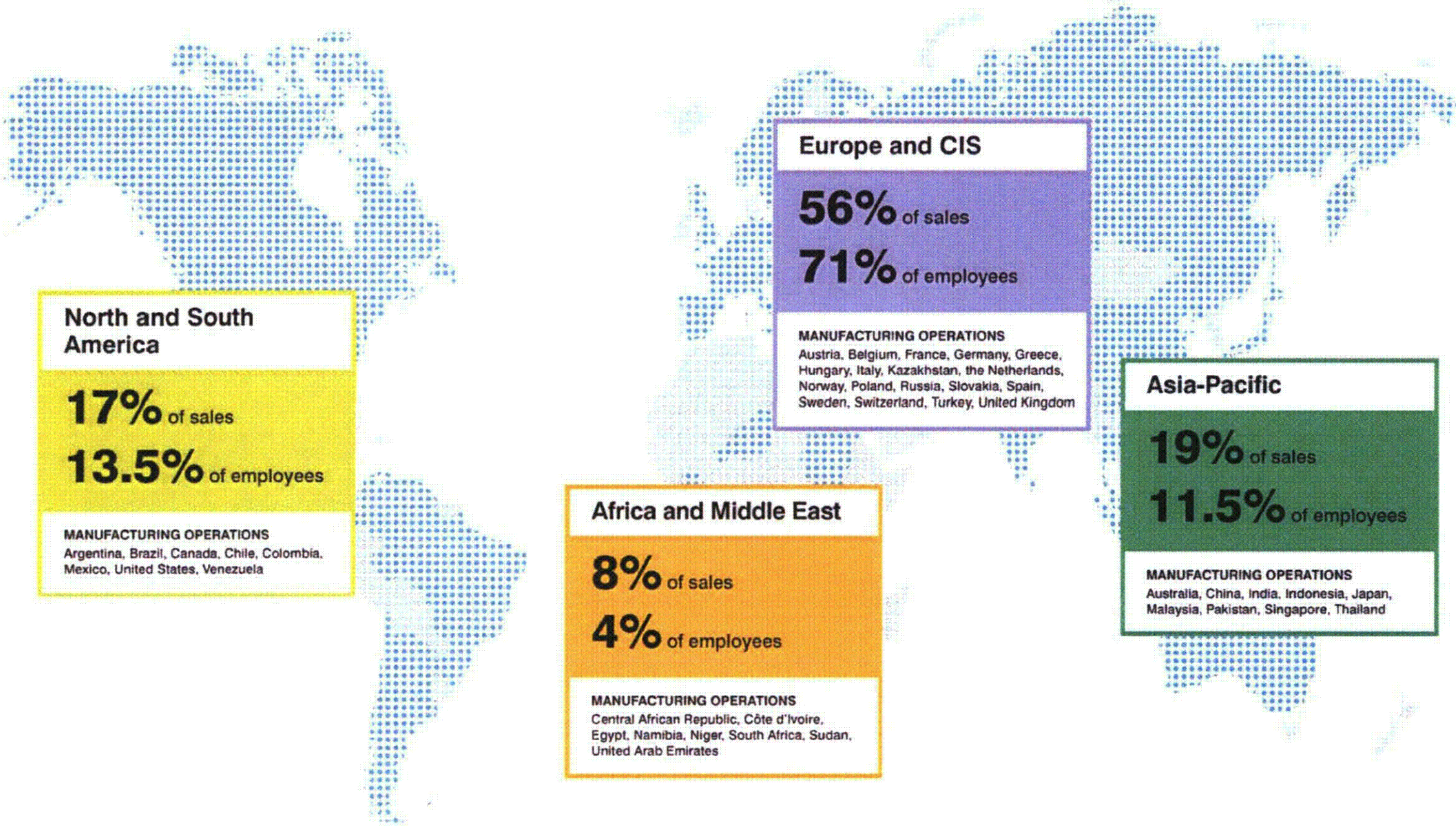
AREVA across the globe

43 countries
Production & Manufacturing

100 countries
Marketing & Sales

Two-thirds of AREVA's sales revenue
came from outside France



Organization of the group

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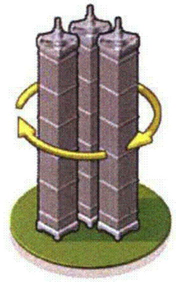
FRONT END

- Mining
- Chemistry
- Enrichment
- Fuel

REACTORS & SERVICES

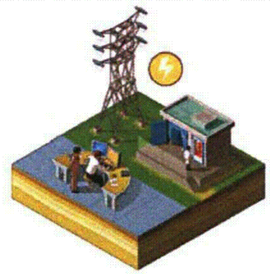
- Plants
- Equipment
- Nuclear Services
- Nuclear Measurement
- Consulting & Information Systems
- AREVA TA
- Renewable Energies

BACK END



- Recycling, logistics, Nuclear site value Development
- Engineering
- Clean-up

TRANSMISSION & DISTRIBUTION



- Products
- Services
- Systems
- Automation

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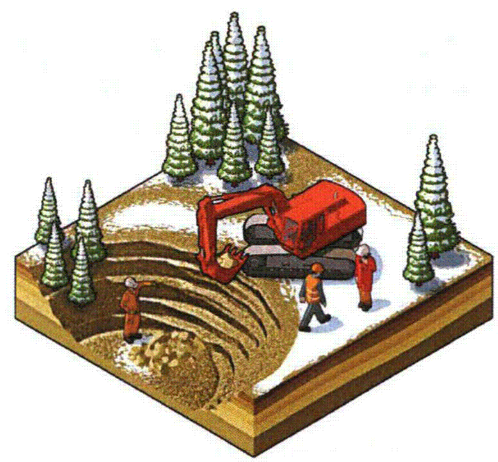
Front End division

- > ***Uranium ore exploration, mining and concentration***
- > ***Uranium conversion and enrichment***
- > ***Nuclear fuel design and fabrication***

12,577
Employees



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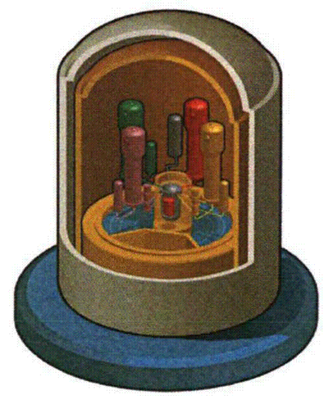
Reactors and Services division

> ***Design and construction of nuclear reactors and other CO2-free power generation systems***

> ***Supply of products and services for nuclear power plant maintenance, upgrades and operations***

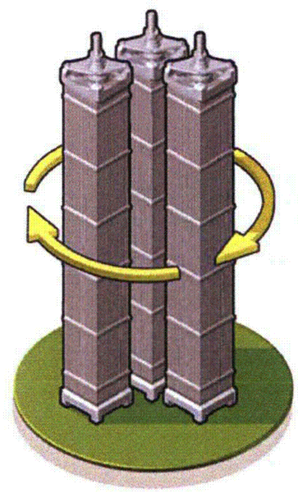


16,500
Employees

Back End division

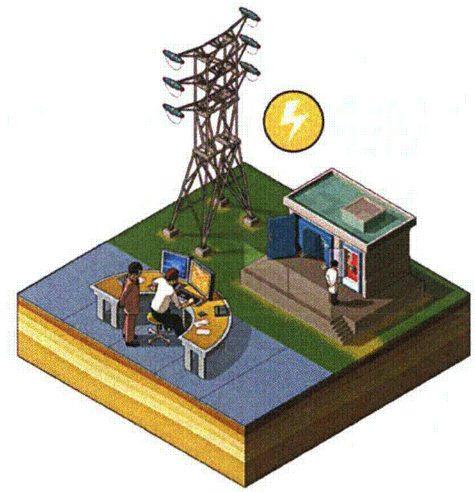
> Treatment and recycling of used nuclear fuel
> Cleanup of nuclear facilities
> Nuclear logistics

10,638
Employees



Transmission & Distribution division

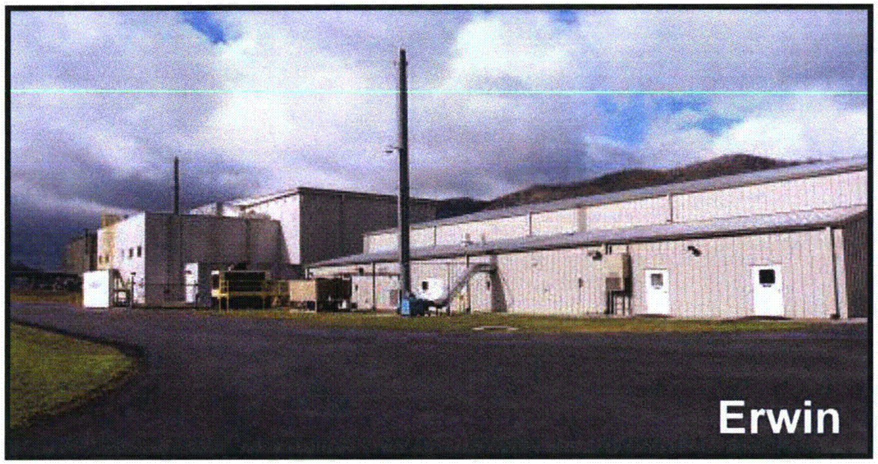
> Supply of products, systems and services for electricity transmission and distribution networks

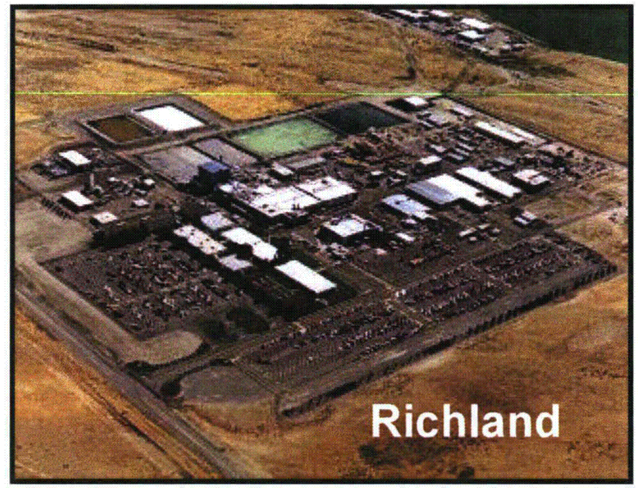


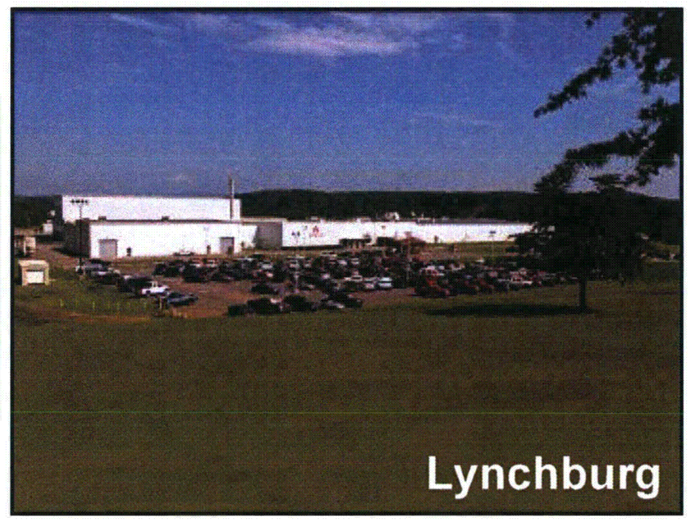
25,248
Employees

AREVA

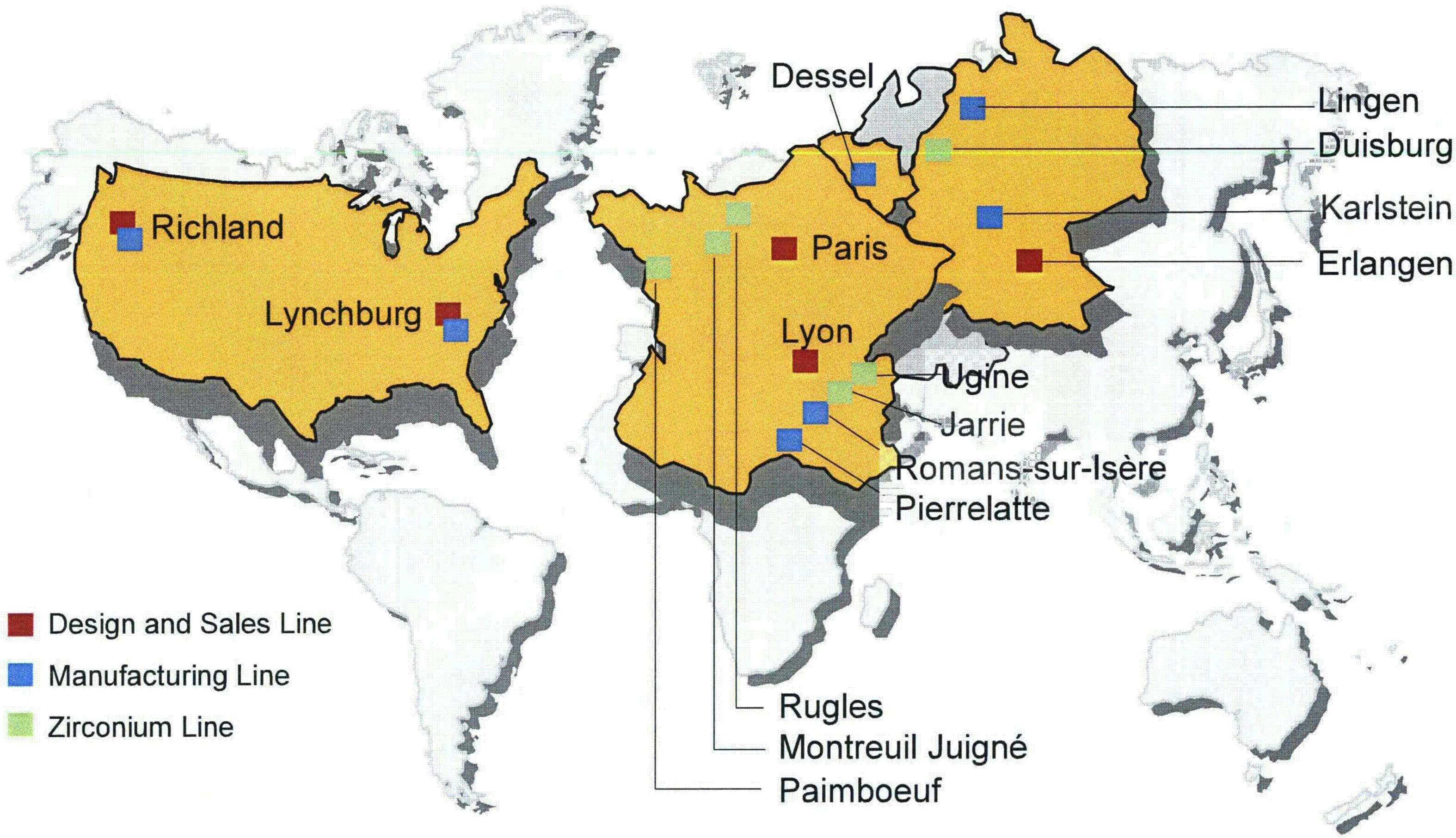
Nuclear Fuel



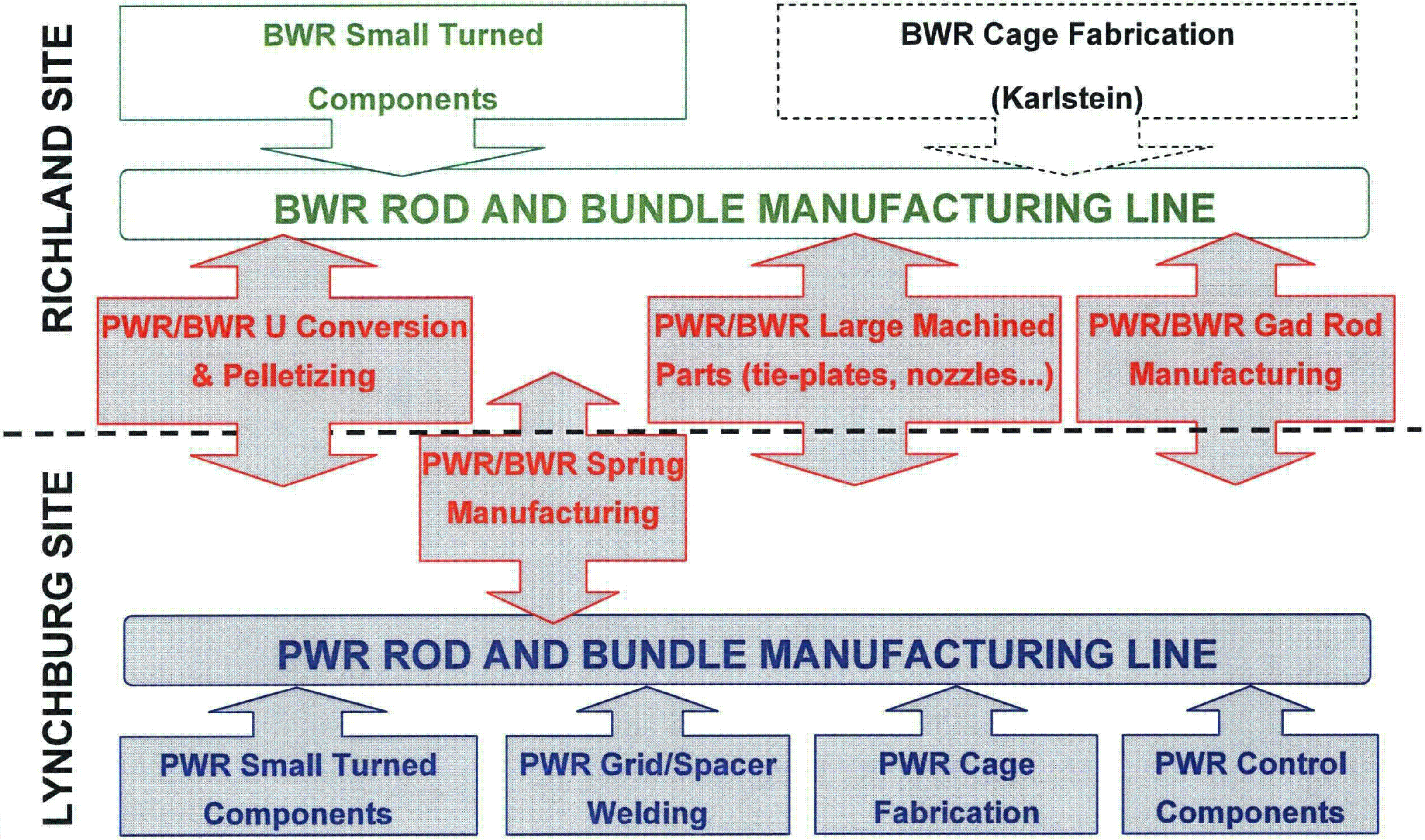




Global Nuclear Fuel and Fuel Component Facilities



Centers of Excellence



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Operations

Mt. Athos Road Facility

- > *Constructed in 1968*
- > *Facility size: 200,000 square feet (Fuel & Nuclear Services)*
- > *Shipped over 15,000 fuel assemblies since 1971*
- > *Shipped over 2,500 incore detectors since 1983*
- > *Fabrication and supply of fuel related components : B_4C and B_4C – Alumina pellets, incore detectors, control components, machined components and springs*
- > *Average workforce experience: 12 years*
- > *Nuclear Services Equipment & Refurbishment facilities on site*
- > *Pump and Motor Services facilities on site*
- > *Certifications: ISO 900, ISO 14001 and OHSAS 18001*

Data as of April 2008

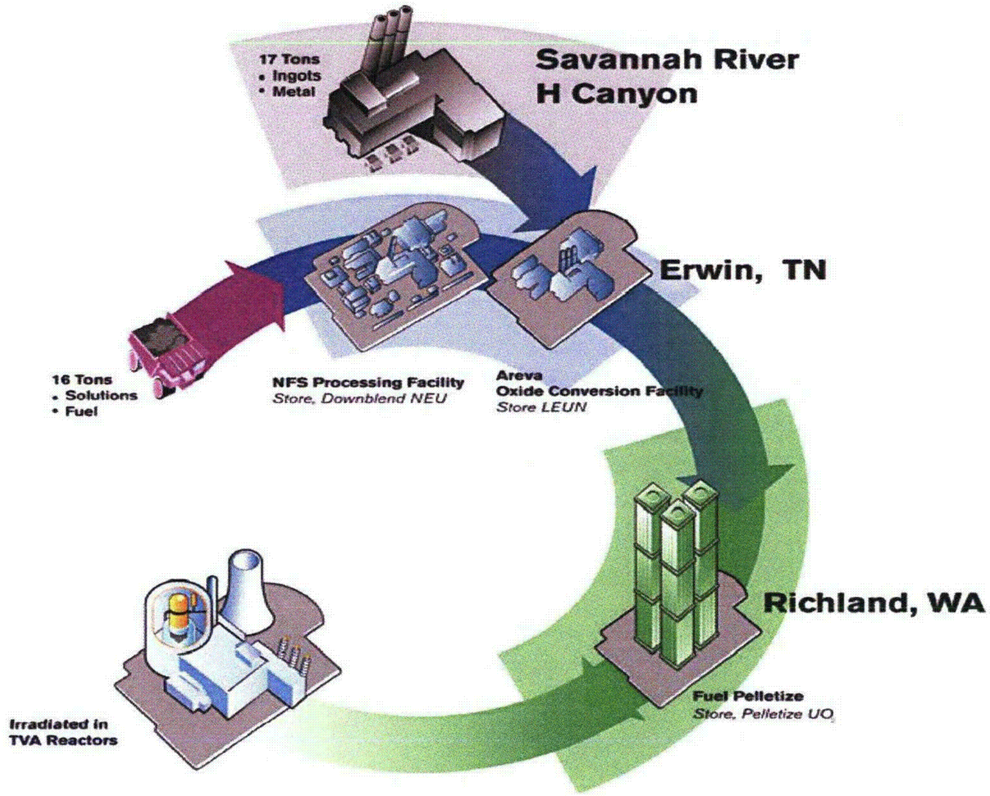
Operations

Horn Rapids Road Facility

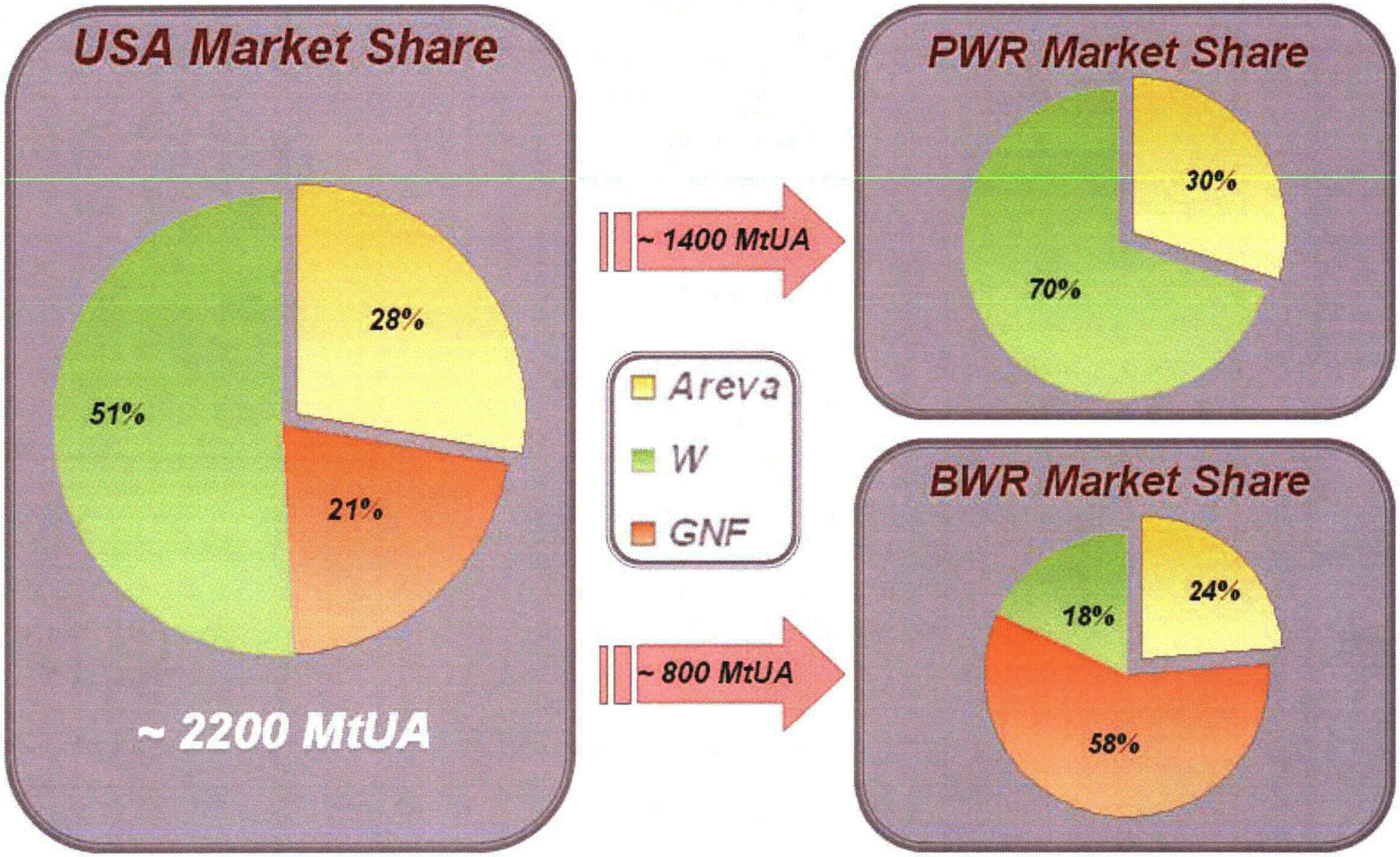
- > Constructed in 1971
- > Facility size: 404,000 square feet
- > Shipped 43,167 fuel assemblies since 1971
  - BWR: 34,642
  - PWR: 8,525
- > 224 powder shipments since 1990
- > 350 pellets / rod shipments since 1989
- > One- millionth ATRIUM™ 10 rods produced – September 2007
- > Average workforce experience: 15 years
- > Analytical and materials laboratories
- > Advanced fuel design testing facilities

Data as of April 2008

Operations
BLEU Conversion Complex



US Fuel Market Share
For External Publication: Updated May 2007



Source: CKA Associates May 22, 2007
Based on 2006-10 commitments

»Information above does not reflect recent awards: Calvert Cliffs 1 & 2 and Browns Ferry 1

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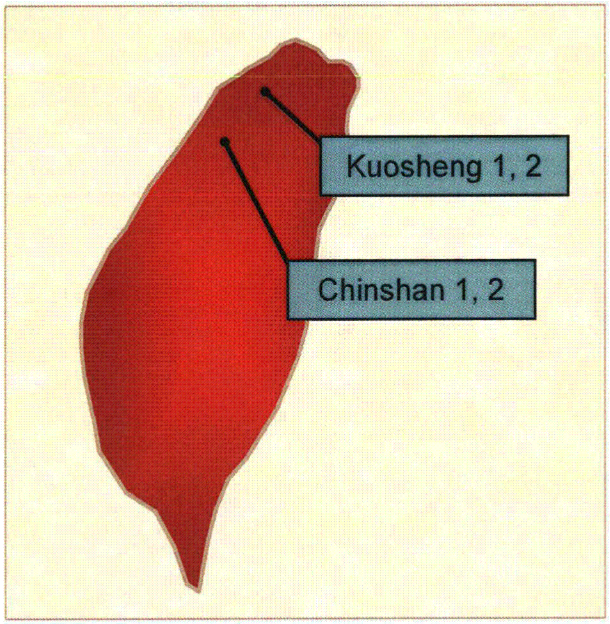
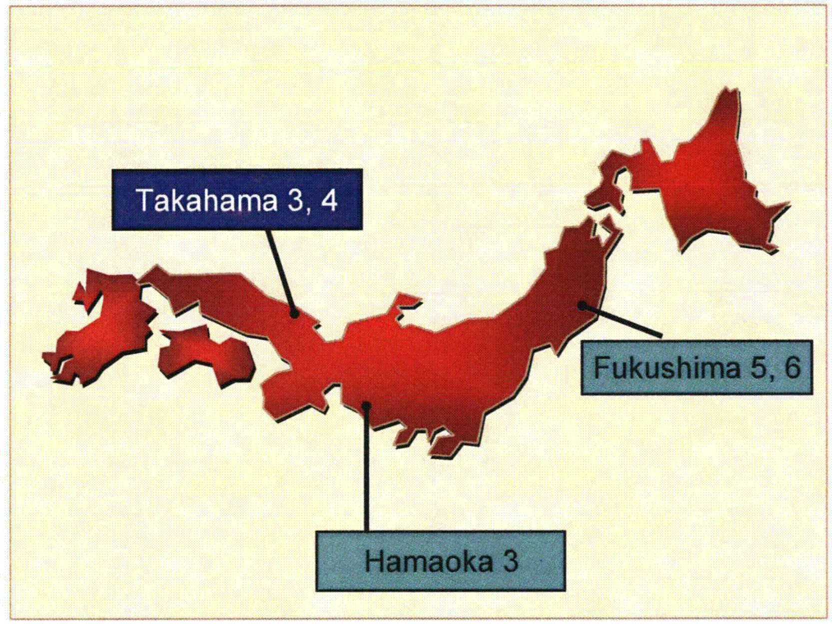
Fuel

AREVA US Fuel Customers

Fuel Customers in Taiwan and Japan



Taiwan



Japan

BWR

PWR

Plans for Future Topical Reports

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Topical Reports - Current

> Topical Reports being reviewed

- ANP-10262, Enhanced Long Term Stability Solution
- BAW-10255, Cycle Specific DIVOM Methodology Using the RAMONA5-FA Code
- ANP-10256, Methodology for Analysis of Control Rod Withdrawal Error for BWR Plants with ARTS

Topical Reports - 2008

> **Topical Reports planned for submittal - 2008**

- EMF-2209, Addendum 1, SPCB Additive Constants for ATRIUM-10 Fuel – April 2008
- BAW-10133, Addendum 3, Revised Seismic Analysis – September 2008
- ANP-102xx, Improved Structural Faulted Analysis Methods – September 2008
- BAW-10255, Revision 3, Cycle-Specific DIVOM Methodology Using the RAMONA5-FA Code – November 2008
- ANP-102xx, Revised BWR Safety Limit Methodology – December 2008
- ANP-102xx, ACE Critical Power Correlation for ATRIUM 10XM – December 2008

Topical Reports - 2009

- **Topical Reports planned for submittal - 2009**
  - ANP-102xx, S-RELAP5 for BWR Non-LOCA Transients – November 2009
  - ANP-102xx, COBRA – FLX Core Transient Thermal Hydraulic Program for PWRs – December 2009
  - ANP-102xx, ARCADIA (ARTEMIS/APOLLO2A) Reactor System Analysis for PWRs – December 2009
  - BAW-10247, Revision 1, Realistic Thermal-Mechanical Fuel Rod Methodology for BWRs (Extension to RXA clad) – December 2009
  - ANP-102xx, High Burnup fuel Performance for PWR Designs > 62K Mwd/Mtu - December 2009

Topical Reports - 2010

> Topical Reports planned for submittal - 2010
  - EMF-2103, Revision 2, S-RELAP5 RLBLOCA Methodology – March 2010

AREVA BWR Fuel Designs and Methods

Norm Garner
Product Manager, BWR Fuel

AREVA

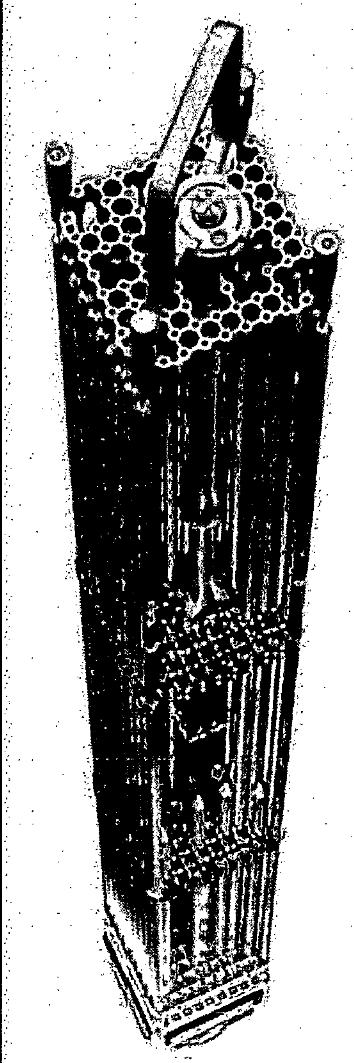
BWR Fuel Designs and Methods

> ## AREVA BWR Fuel Designs
- Overview of BWR Products
- Component Upgrades for Reliability Improvement
- Fuel Channel Enhancements

> ## AREVA BWR Codes & Methods
- Recent Advances
- Continuing Development

AREVA BWR Fuel Designs

AREVA Fuel Designs for BWRs



ATRIUM™ 10 (A/B)

> Proven and reliable high performing, well-balanced fuel design

ATRIUM™ 10XP

> Higher fuel weight and stability

ATRIUM™ 10XM

> Short- and long-cycle versions

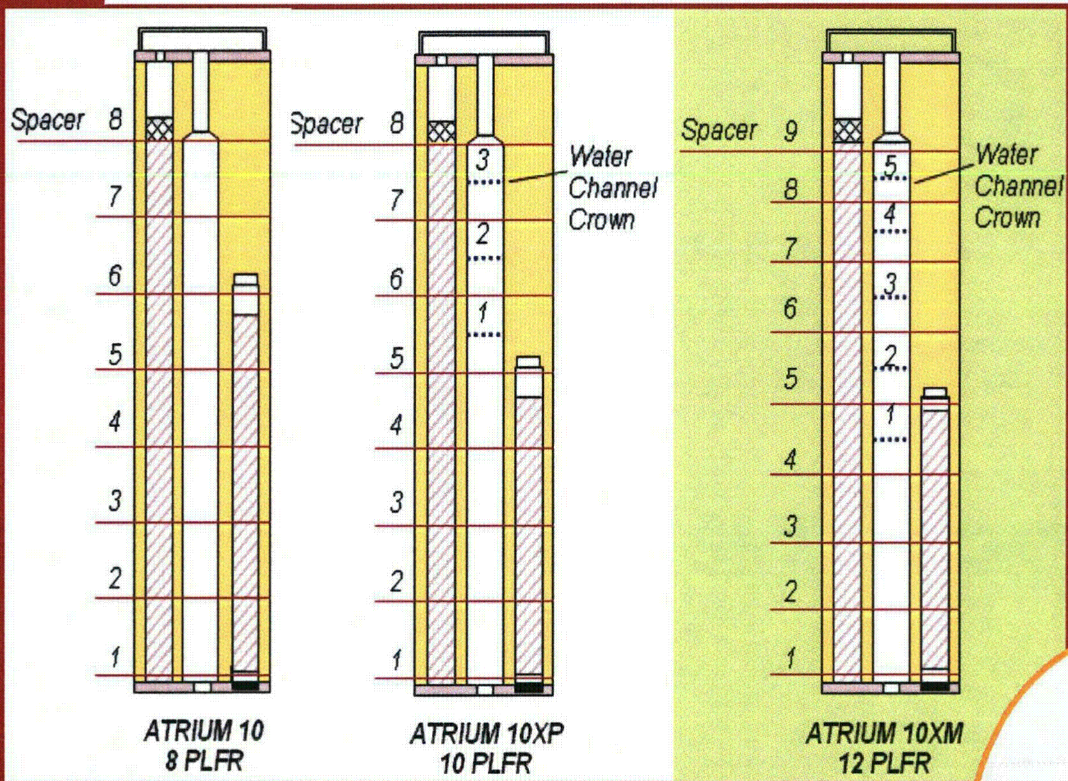
> Superior critical power capability

> Superior cold shutdown margin and reduced gadolinium requirements

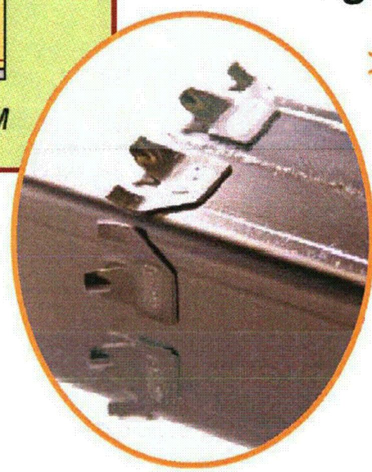
ATRIUM is a trademark of AREVA NP

AREVA

ATRIUM™ 10x10 Fuel Designs
Increasing Critical Power Capability



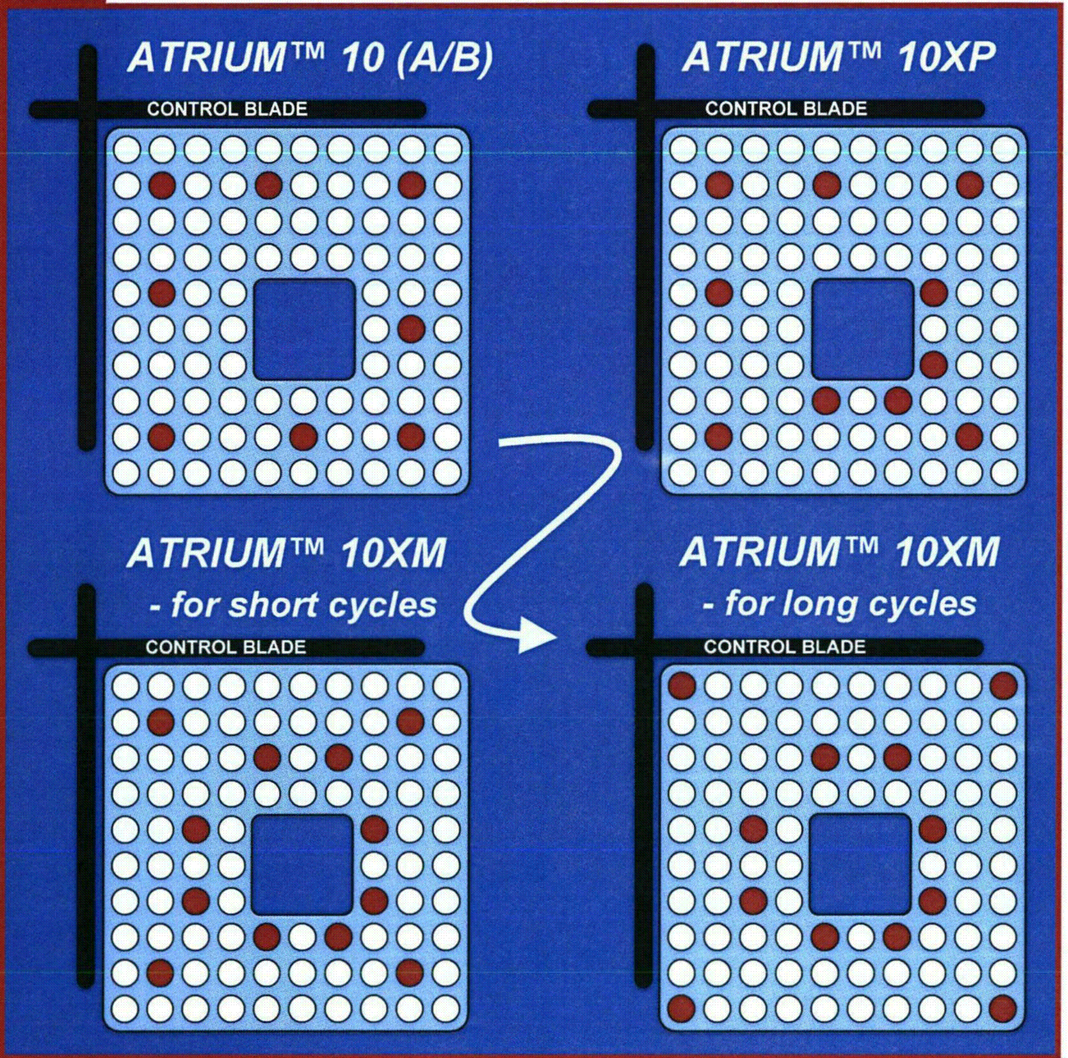
- **_Additional spacer grid_**
  - **_Extends critical power capability for ATRIUM™ 10x10 configuration_**
- **_Progressively smaller spacer spans_**
  - **_Optimizes critical power capability in high void elevations_**
- **_Water channel crown_**
  - **_Strips liquid film from water channel for use in fuel rod cooling_**



Use of common components builds on successful experience

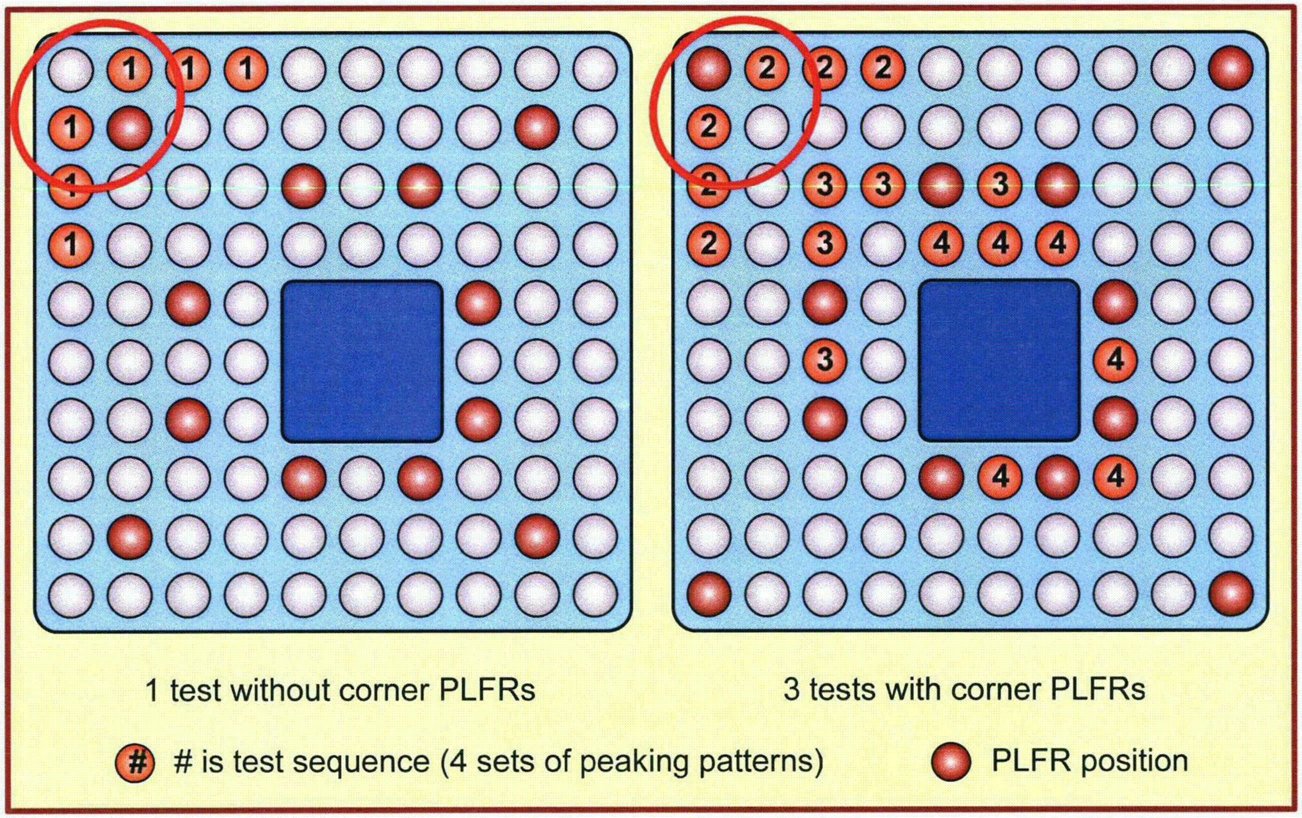
ATRIUM™ 10x10 Fuel Designs

Increasing Stability, Mass, and Critical Power Capability



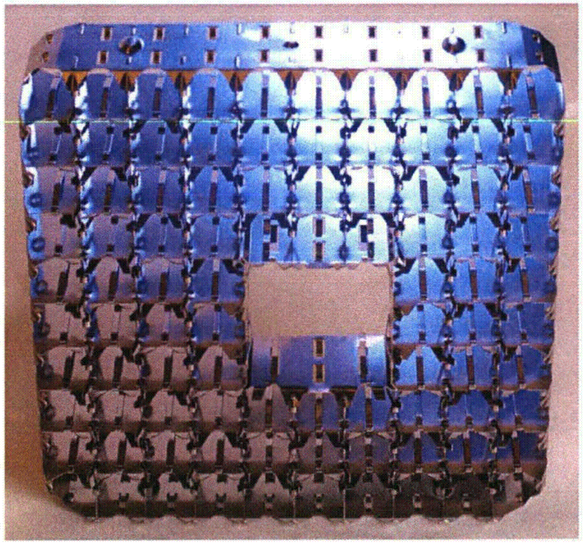
- Larger fuel rod diameter for ATRIUM™ 10XP & 10XM
  - More efficient fuel-to-moderator distribution
  - Proportional increase in cladding wall thickness for reliability
- Part-length fuel rod (PLFR) number and length selected to meet pressure drop and stability requirements
- PLFR placement selected to provide critical power and shutdown margin benefits

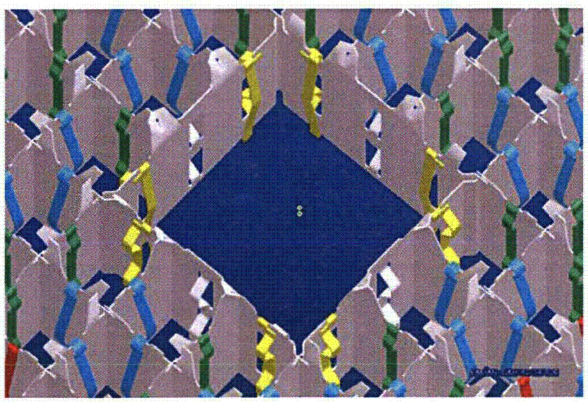
ATRIUM™ 10XM Critical Power Capability - Demonstrated by Rigorous Testing



- **_PLFR placement for neutronic benefits must be carefully evaluated with respect to impact on local thermal performance_**
- **_Relocation of corner PLFRs for long-cycle ATRIUM™ 10XM has been explicitly tested with limiting upskew power profile_**

ATRIUM 10XM Spacer Grid ULTRAFLOW Type 62





> ***Structure and fuel rod support features continue proven reliability of the ATRIUM 10 ULTRAFLOW grid***

> ***Extensive operational experience in both ATRIUM 10XP and ATRIUM 10XM fuel designs***
- ***>3800 in use, burnup to 52 GWd/MTU***
- ***LFAs since 2002***
- ***Reloads since 2005***

> ***Vaned egg-crate style grid with limited flow path obstruction***
- ***Solid strips reduce pressure drop and potential for debris capture***

> ***Structure is fabricated from Alloy 718 sheet for low pressure drop and dimensional stability throughout life***

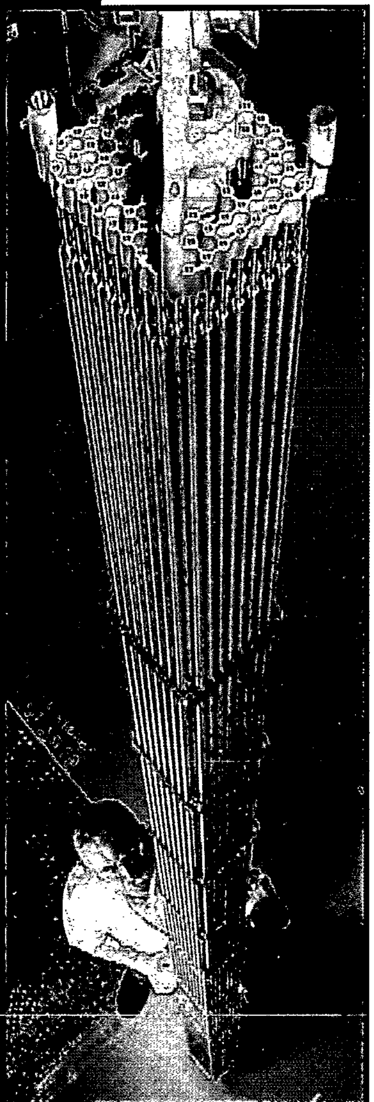
Advanced ATRIUM™ 10 Operational Experience

Plant	Plant Type	ATRIUM™ Type	First Delivery	Number Irradiated Bundles	Rods	Peak Burnup GWd/MTU
C04	Siemens KWU	10XP	2002	60	5,460	52
C05	Siemens KWU	10XP	2006	136	12,376	5
C22	GE BWR/6	10XP 10XM	2003 2005	16 4	1,456 364	40 21
C21	Siemens KWU	10XP	2004	92	8,372	24
C12	ASEA	10XP	2004	4	364	29
C24	ASEA	10XM	2006	4	364	7
C20	GE BWR/6	10XP	2005	32	2,912	12
C11	Siemens KWU	10XP	2006	112	10,192	12
C10	Siemens KWU	10XP	2006	20	1,820	12
Total as of January 2008				480	43,680	52

Extensive irradiation experience and PIE data provides confidence in ATRIUM™ 10XM operational reliability

US Introduction of the ATRIUM™ 10XM - LTA Plans

ATRIUM™ 10XM Readiness for US Market



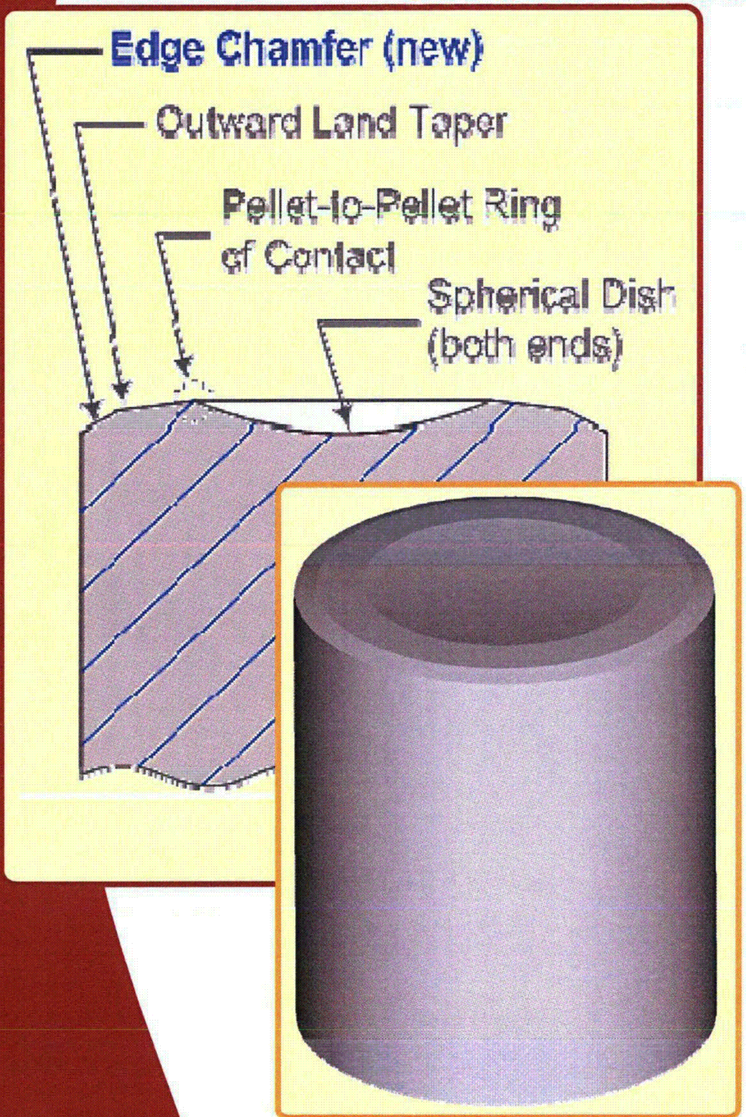
- The ATRIUM 10XM is intended to replace the ATRIUM 10 as AREVA's mainline BWR fuel product for the US market
- Significant operating experience base in Europe and evolutionary design of the ATRIUM™ 10XM supports a rapid progression to US reload supply

Component Upgrades for Reliability Improvement

BWR Fuel Reliability Challenges

- Debris fretting and non-classical PCI are primary causes of BWR fuel rod failure for AREVA
- Non-classical PCI is being addressed through several approaches:
  - Manufacturing – Tightened specifications, improved inspection, Lean Six Sigma process controls, Automated Pellet Inspection System
  - Operating guidelines – REMACCX-10, Rev. 3 recently issued, XEDOR online fuel condition monitoring to be released in mid-2008 for operational testing
  - Design – Improved pellet geometry
- Rigorous attention to Foreign Material Exclusion practices at fuel fabrication and nuclear stations remains a high priority, but
  - Design responses can also further enhance debris resistance

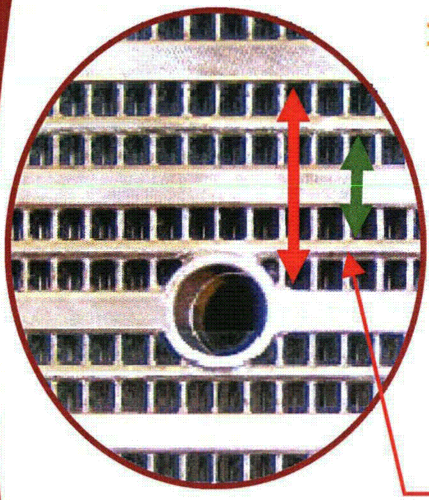
Improved Fuel Pellet Geometry - Chamfered Design for BWR 10x10 Fuel



- ***AREVA ceramic experts have established a preferred global standard geometry for fuel pellets***
  - ***Retains favorable outward land taper, dished end, and ~1.2 length-to-diameter ratio of current pellet***
  - ***Adds small edge chamfer at both ends***
- ***Edge chamfer reduces pellet susceptibility to chipping***
  - ***Supplements tightened MPS specifications and pending automated pellet inspections***

Effective design response to reducing Missing Pellet Surface conditions

AREVA FUELGUARD™ Lower Tie Plate
- Enhanced Design Developments



- *Step 1: Interim enhancement to limit wire length capable of passing through grid*
  - *Reload delivery to Brunswick 1Q08*
  - *Wire length limited by length that can pivot around bars on exit side of grid*
  - *Extra bars will reduce passable wire length*

Extra bars between standard FUELGUARD™ bars

Chromia Doped Fuel

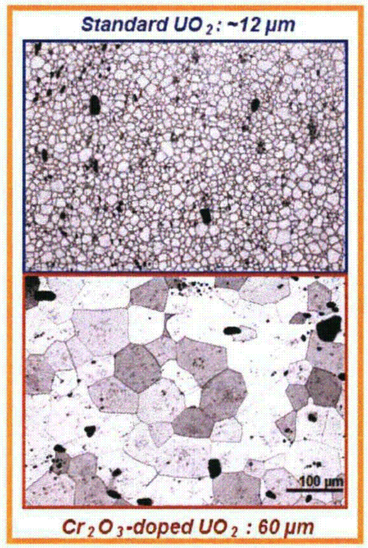
> Chromia doped fuel is fabricated by adding Cr_2O_3 into the pellet powder blend [ ]

> Key benefits:

- Increased pellet plasticity relieves stress on cladding under PCI conditions – power ramp capability at least comparable to benefit of liner vs. non-liner cladding
- Large grain size and low resintering of Cr-doped fuel reduces release of fission gas to plenum – supports higher steady-state power while still meeting EOL fuel rod gas pressure criteria
- Cr-doped pellets are stronger and less susceptible to chipping than standard UO2 pellets
- In the event of a primary failure, pellet degradation is significantly reduced – limits secondary damage risk of cladding splits and/or fuel washout

Chromia Doped Fuel Program Status
- Development Steps

- Development from late 1980's to late 1990's established optimal chromia addition concentration and pellet grain size characteristics
- Extensive qualification is underway, including poolside and hot cell PIE and ramp testing, to fully characterize benefits
- **Optimized Cr-doped fuel is bounded by standard fuel behavior and introduces no new failure mode risk**



Fuel Channel Enhancements

Fuel Channel Enhancements
Observations from Channel Bow Investigations

> *Ideal fuel channel characteristics:*

1. *Low general corrosion*
2. *Low shadow corrosion sensitivity*
3. *Low hydrogen pickup fraction*
4. *Low fluence-induced growth*

> *Zircaloy-2*

- *Shadow corrosion sensitivity and higher hydrogen pickup than Zry-4 appear to be key to observations of abnormal bow*

> *Zircaloy-4*

- *Zircaloy-4 exhibits the desired low shadow corrosion sensitivity and low hydrogen pickup characteristics*
- *General corrosion is higher than Zircaloy-2, but satisfactory for current US burnups and chemistry practices*
- *Fluence-induced growth is satisfactory for current US burnups and operating strategies*

New materials/processes can increase margin for current demands and support readiness for evolving demands

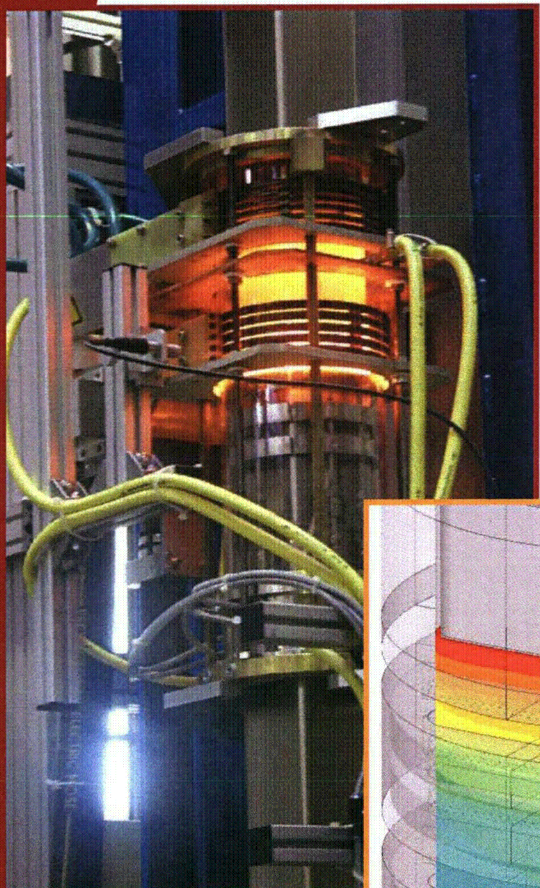
Fuel Channel Enhancements
Advanced Alloy – Zircaloy-BWR

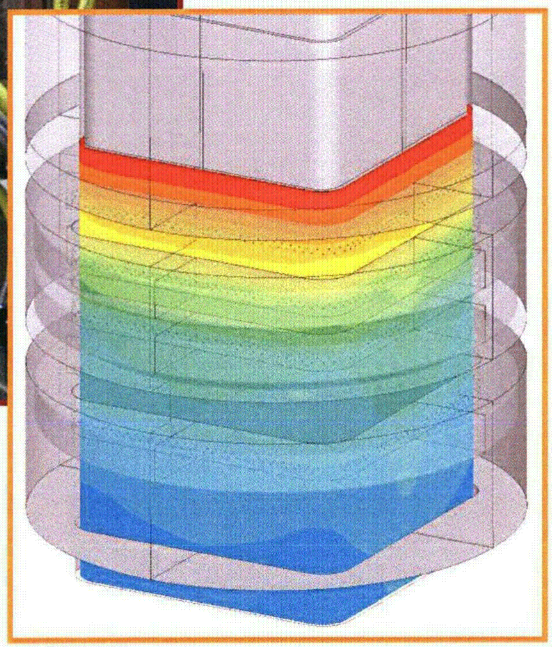
> ***Zry-BWR exhibits most of the desired characteristics of an ideal fuel channel material:***
>
> - ***Low general corrosion, low hydrogen pickup, and low shadow corrosion sensitivity***

> ***Essentially Zry-4 with Fe and Cr above ASTM limits***

Significant operating experience and PIE data is available to confirm performance characteristics (above comparison for concurrently operated spacer grids at 58 GWd/MTU)

Fuel Channel Enhancements
β-quench at Near-Final Geometry





> **AREVA has developed a proprietary process to β-quench fuel channels**
  - ***Eliminates sheet rolling texture and randomizes crystal alignment ➔ leading to near-zero fluence-induced growth***

1. ***Channel is locally heated into β-phase region and held a short time - inert cover gas (argon) precludes oxidation and scaling***
2. ***Channel is rapidly quenched to yield random crystallographic orientation***
3. ***Final sizing and heat treatment for corrosion resistance (SPP size and distribution) is then completed***

β-Quench Lead Fuel Channel Performance

[

]

Lead β-quench treated fuel channels are showing near-zero growth after three annual cycles

Fuel Channel Enhancements
Lead Introduction Plans

AREVA BWR Codes & Methods

BWR Methodology Transformation

> BWR industry is being transformed
  - Extended Power Uprates & Flow Domains (MELLLA+)
  - Margin Improvements
  - Zero Fuel Failures by 2010
  - Advanced Fuel Designs

> Diverse projects are currently active to transform our historical approaches
  - Validation – revisiting basis of current methods
  - Evolution - improved physical modeling
  - Innovation - novel solutions

Industry needs and licensing environment are rapidly changing

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Support for Evolving Operating Domains

> Generically approved methods have been revalidated for application in new domains

> Extended Operating Domains have resulted in extensive interactions with the NRC & ACRS addressing both established and new methods

> 2007 Susquehanna CPPU submittal provided first AREVA application for EPU:

- Small penalty due to limited Gamma Scan Data (MCPRSL)
- Small penalty to cover uncertainties in bypass boiling impact on OPRM set-point

Review and outcome recognized strength and thorough validation of AREVA methods

Major Developments in 2007

> 2007 saw significant methodology advances...

- *ACE/ATRIUM-10 critical power correlation approved*

[ ]

- *RODEX4 draft Safety Evaluation Report Received*
  - *First statistically based Thermal-Mechanical methodology in the industry*
  - *Predicts both steady-state and transient response of fuel rods*
- *Enhanced Option III and DIVOM Methodology draft Safety Evaluation Report Received*
  - *Provides physically correct approach for extended flow domains*

Continuing Developments in 2008

> Steady progress on improvements…
- MICROBURN-B2
  - Continued benchmarking and evaluation against current operation
- SAFLIM-3D
  - Revised Safety Limit Methodology for use with the ACE correlation
    - MICROBURN-B2 based channel bow uncertainties developed for RODEX4 statistical methodology
  - Programming complete and ready for testing
- AURORA-B (S-RELAP5 based transient methodology)
  - Single FORTRAN-90 executable for Non-LOCA, SBLOCA, RLBLOCA and BWR AOO – Reduced HU issues
  - RODEX4 models implemented
  - MB2-K extensions including enhancements to support reactivity insertion accident analysis
  - All major elements of the methodology are now in place and awaiting assessment

Methodology Support for Improved Fuel Reliability

> **Realization of innovative approaches…**

- **XEDOR**
  - Reduced order model (ROM) to predict local clad stresses
    - Fundamental relationships based on RODEX4 models
    - ROM allows execution speed sufficient to allow on-line monitoring of every rod in every node of the core
      - > 1 Million stress calculations for each burn step
  - XEDOR has been implemented within MICROBURN-B2
  - Successfully used to perform full core stress surveys in support of fuel failure analysis and NRC/ACRS questions on CPPU
  - XEDOR calculations are being assessed by EPRI/Anatech

Redefines the online monitoring paradigm in support of Zero Fuel Failures by 2010

XEDOR Capability

[ ]

Continued Support for Extended Domains

> Continued review of AREVA methods is expected for follow-on CPPU or MELLLA+ applications
  - Identified concerns from Susquehanna CPPU
    - Limited gamma scan data
    - Uncertainty due to limited void fraction qualification at high qualities
    - Bypass Voiding impact on OPRM and APRM systems
      - Being addressed in DIVOM / Enhanced Option III RAIs
    - ATWS/Instability
      - required for MELLLA+ applications

AREVA continues to strengthen the validation basis of its methods as applied to extended domains to meet regulatory expectations

Programs to Be Completed in 2008 - Licensing Methods

> 2008 Methodology Evolution
- RODEX4
  - Extend methodology for RXA cladding
  - Finalize automation tools
- Enhanced Option III and DIVOM
  - Respond to four NRC RAIs rising from ACRS concerns
  - Facilitate review of RAMONA5-FA
- Critical Power Performance
  - Submit SAFLIM-3D
  - Submit ACE/ATRIUM-10XM
  - Complete AURORA-B assessments and sample applications

Programs to Be Completed in 2008 - New Innovations

> 2008 Innovation

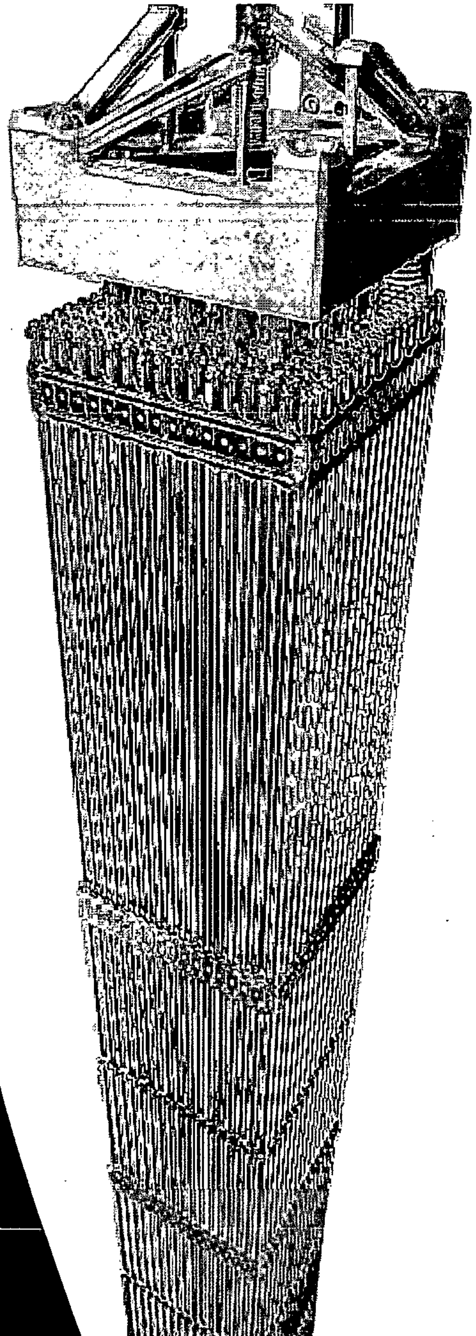
- XEDOR
  - Complete qualification of method against ramp data base and fuel failure experience
  - Collaborate with reactor operators to optimize monitoring functions
  - Prepare training program to facilitate learning

AREVA BWR Codes & Methods - Conclusions

> AREVA is helping to transform the BWR industry

- Successfully validating current methods to support greater energy production from existing fleet
- Enhancing both the physical models and the calculational methodology to maximize fuel utilization
- Actively pursing advanced fuel designs and validation data to meet customer and regulator expectations
- Applying true innovation to address Zero Fuel Failures by 2010

AREVA is dedicated to exceeding industry expectations



PWR Fuel Designs and Methods

Graydon Uyeda
PWR Product Manager

PWR Product Overview

> **Advanced Mark-BW Design**
- Used in Westinghouse 17x17 Plants
- Design Variants: Mark-BW, Advanced Mark-BW, and Advanced Mark-BW(A)
- Design Utilized for MOX Program

> **Mark-B Design**
- Used in Babcock & Wilcox 15x15 Plants
- Current Design Variants: Mark-B11, Mark-B12 and Mark-B-HTP

> **HTP™ Design**
- Design concept applicable to B&W, CE, Framatome ANP, Siemens KWU and Westinghouse Plants (14x14 to 18x18 Arrays)
- EPR Reactor will utilize a 14' HTP design

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Outline of Presentation

> Advanced Mark-BW Design Overview
  - Design Features
  - Operating Experience
  - Planned Enhancements

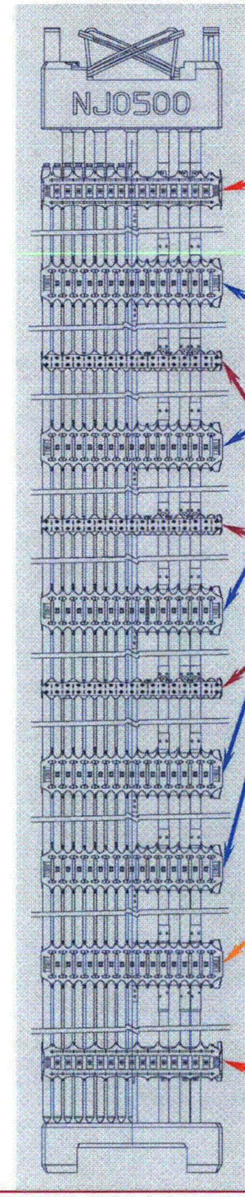
> Mark-B Design Overview

> HTP Design Overview

> New PWR Fuel Design Development

Overview of Advanced Mark-BW Assembly

- **Removable Upper End Fitting**
  - *Alloy 718 Leaf Springs*
  - *Quick Disconnect Feature*
- **M5® Fuel Rods**
- **M5 Guide Tubes**
- **M5 Instrument Tubes**
- **TRAPPER™ Lower End Fitting**



- **Alloy 718 Top Grid**
- **M5 Mixing Grids**
- **M5 Mid-Span Mixing Grids (optional)**
- **M5 Non-Vaned Grid (offered with vane version)**
- **Alloy 718 Lower Grid**

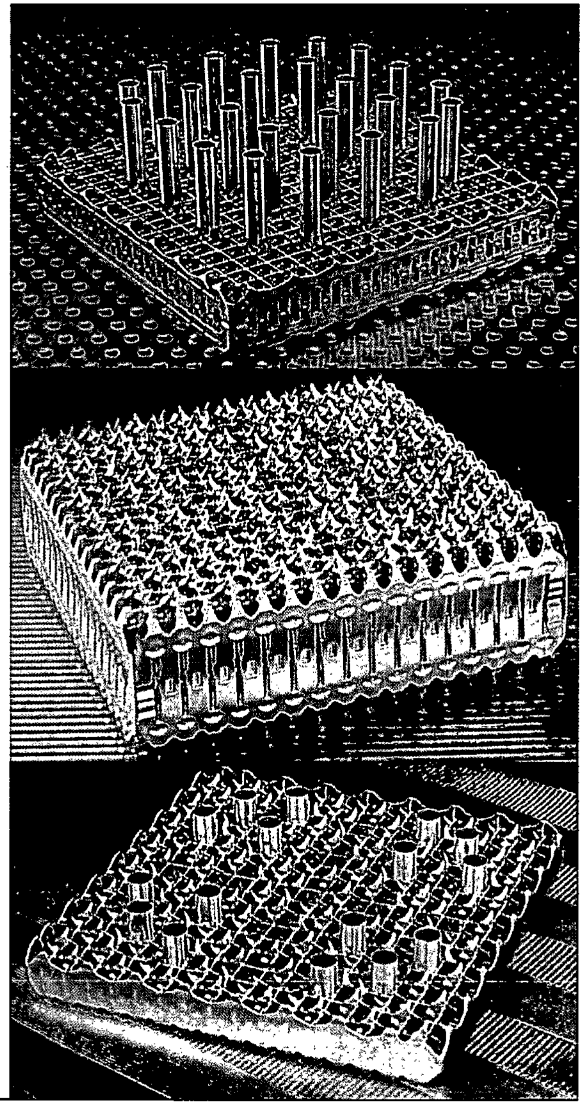
Design Features – Utilizes Alloy M5

> ***Applicable Components:***
  - *Fuel Rods*
  - *Guide Tubes / Instrument Tubes*
  - *Intermediate Grids and Mid-Span Mixing Grids*

> ***Performance with M5 (vs. Zircaloy-4)***
  - *3 to 4x <u>Lower Corrosion</u> at High Burnup*
    - *Greater Margin at Higher Burnups*
  - *<u>Very low sensitivity</u> to reactor duty factors (i.e., heat flux, temperatures and power)*
  - *Licensed by the USNRC (December 1999)*

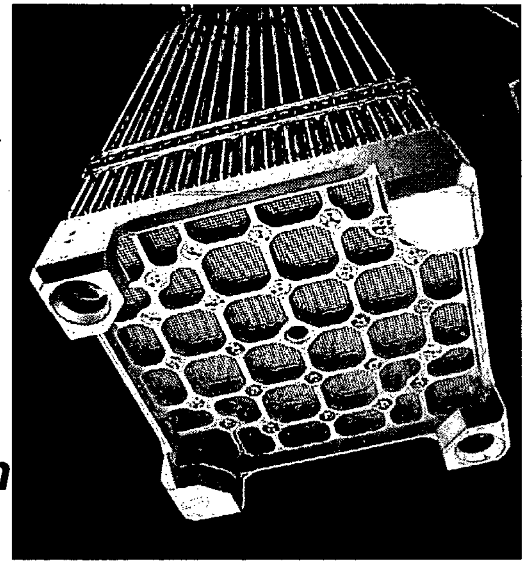
Design Features – Spacer Grids

- End Grids – Alloy 718 (Low Cobalt)
  - Utilized at bottom and top positions
  - Non-vaned
- Intermediate Grids – M5
  - Optimized mixing vanes
  - Non-vaned version available for lower region
  - Wide support – fretting resistance
  - Handling robustness
- Mid-Span Mixing Grid – M5
  - Added thermal performance

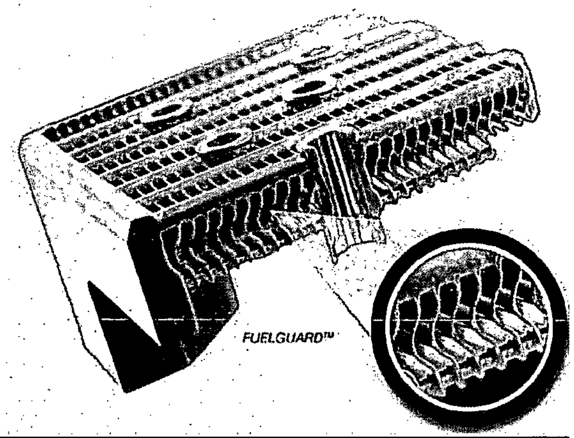


Design Features – Lower End Fitting

> TRAPPER Plate
- Cast Frame and Web
  - Provides structural support
  - Accommodates attachment of guide tubes with secured cap screws
- No debris passing through TRAPPER has caused failures since introduction (over 2,500)
- Two Mesh sizes offered



> FUELGUARD™ Offered with Advanced Mark-BW(A)
- No debris passing through FUELGUARD has caused failures since introduction (over 6,300)



Operating Experience – Mark-BW Fuel Assembly

Mark-BW Operating Experience

> Current Mark-BW Experience Summary

Unit	First Delivered	Batches	+	LFAs	Assemblies
Catawba-1	1991/2005	7	+	4	524
Catawba-2	1993	5			404
McGuire-1	1987/1991	7	+	4	512
McGuire-2	1991	6			448
North Anna-1	1997/2004	3	+	4	193
North Anna-2	2004	3			189
Sequoyah-1	1997	8			625
Sequoyah-2	1997/1999	7	+	4	571
Trojan	1990/1991	1	+	4	48
TOTAL		47	+	20	3,518

Planned Enhancements

Outline of Presentation

> Advanced Mark-BW Design Overview

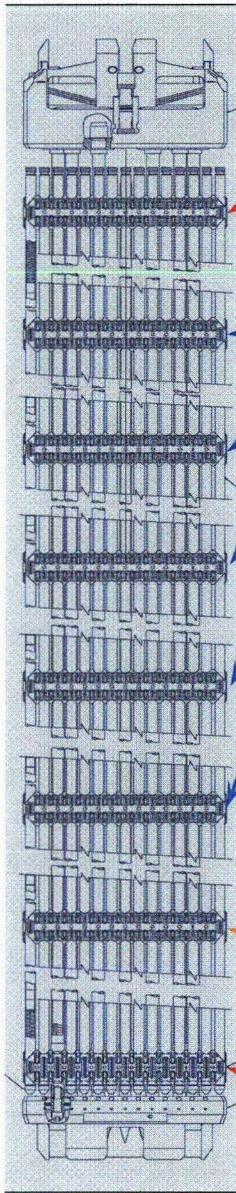
> **Mark-B Design Overview**
- **Design Features**
- **Operating Experience**
- **Planned Enhancements**

> HTP Design Overview

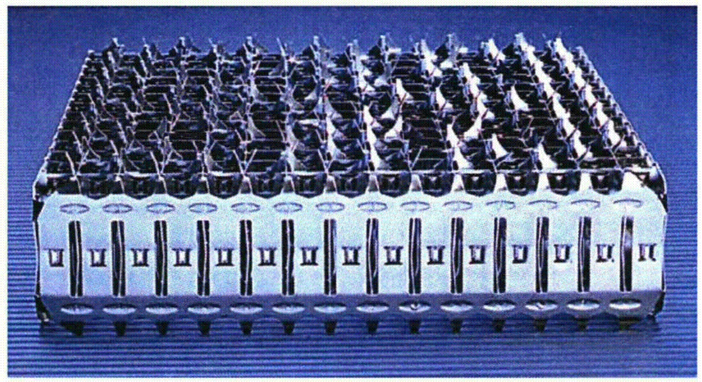
> New PWR Fuel Design Development

Overview of Current Mark-B Fuel Assemblies

- **Removable Upper End Fitting**
  - *Alloy 718 Cruciform Springs*
  - *"Quick Disconnect" on Mark-B11*
- **M5 Fuel Rods**
- **M5 Guide Tube**
- **Lower End Fitting**
  - *Mark-B11: Plug-in-Grid*
  - *Mark-B12: TRAPPER*



- **Alloy 718 Top Grid**
- **Zirc-4 Intermediate Grids** *(Mark-B11 Utilizes Mixing Vanes)*



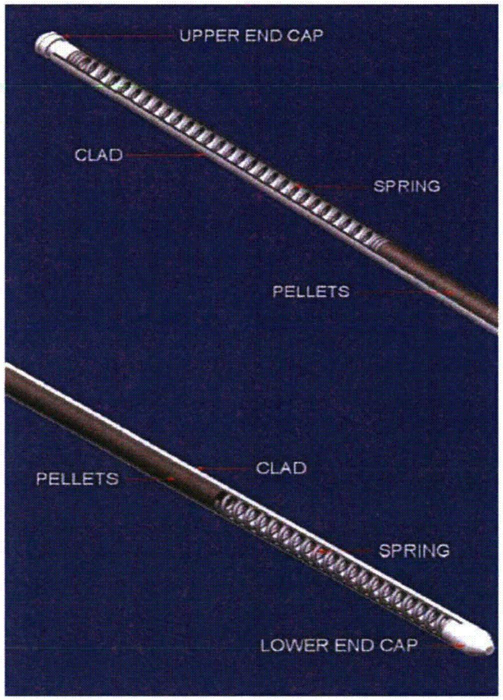
- **Zirc-4 Vaneless Grid**
- **Alloy 718 Lower Grid**

Design Features – Fuel Rods

> **Application of M5**
  - Increased Corrosion Protection
  - Reduced Hydrogen Pickup
  - Improved Growth Behavior

> **Mark-B11**
  - Reduced Diameter (0.416 inch) for 18 Month Cycle Operation
  - Long Lower End Cap in Lower Grid for Debris Protection
  - Stainless Steel Upper Plenum Spring

> **Mark-B12 / Mark-B-HTP**
  - Heavier Loaded Fuel Rod (0.430 Inch) for 24 Month Cycle Operation
  - Stainless Steel Upper and Lower Plenum Springs



Operating Experience – Mark-B Fuel Assemblies

> > 9,800 Mark-B Fuel Assemblies delivered since 1972

> Proven Experience in eight US Reactors (Typically 18 and 24-Month Cycles)

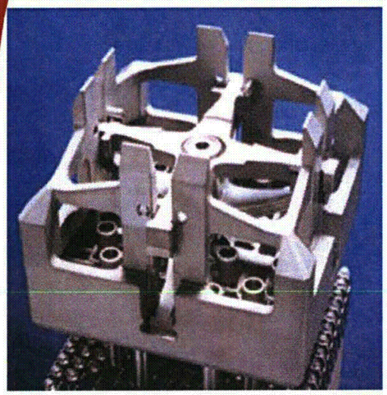
Unit	Batches	Fuel Assemblies
Oconee-1	25	1,487
Oconee-2	24	1,441
Oconee-3	25	1,465
Crystal River-3	15+2*	997 + 169*
ANO-1	21+1*	1,277 + 56*
Davis-Besse	16+1*	997 + 76*
Three Mile Island-1	18	1,205
Three Mile Island-2	3	177
Rancho Seco	9	493
TOTAL	160	9,840

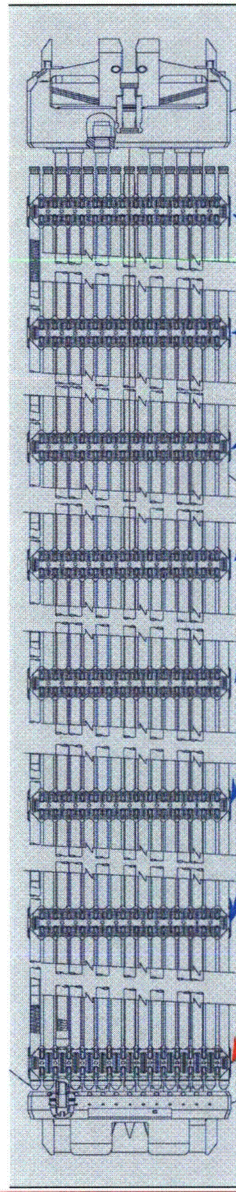
* Mark-B-HTP Product

Planned Mark-B Enhancements – Mark-B-HTP

- Transition to Mark-B-HTP on Customer Need
  - First Cycle operated well in Crystal River-3 (since Fall 2003)
  - Third Batch (Full Core) in Operation at CR-3
  - Second Batch and Cycle at ANO-1 and Davis-Besse
  - First Batch and Cycle at TMI
  - Introduction into Oconee Unit's to Begin Late 2008
- Key Design Features of Mark-B-HTP (Overview Next Slide)
  - Same Upper End Fitting and Guide Tubes
  - Mark-B12 Rod
  - Welded Structure (Guide Tube to HTP Grid Connections)
  - Seven M5 HTP Grids (CR-3, Cycle 14 Used Zirc-4)
  - Lower Alloy 718 HMP™ Grid
  - FUELGUARD Lower End Fitting

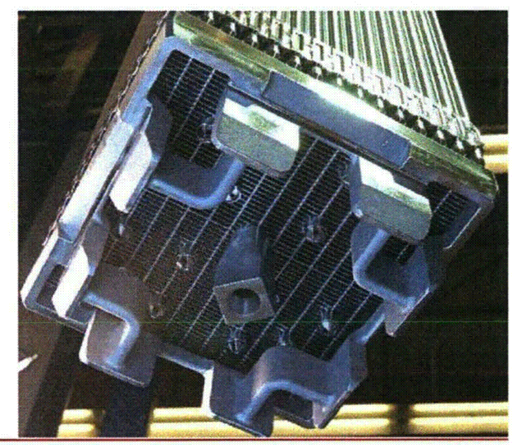
Overview of Mark-B-HTP Fuel Assembly





- ***Removable Upper End Fitting***
  - *Alloy 718 Cruciform Springs*
- ***M5 Fuel Rods***
- ***M5 Guide Tube***
- ***M5 Instrument Tube***
- ***FUELGUARD Lower End Fitting***

- ***M5 HTP Grids (7x)***
- ***Alloy 718 Lower HMP Grid***



Outline of Presentation

> Advanced Mark-BW Design Overview

> Mark-B Design Overview

> **HTP Design Overview**
> - **Design Features**
> - **Operating Experience**
> - **Planned Enhancements**

> New PWR Fuel Design Development

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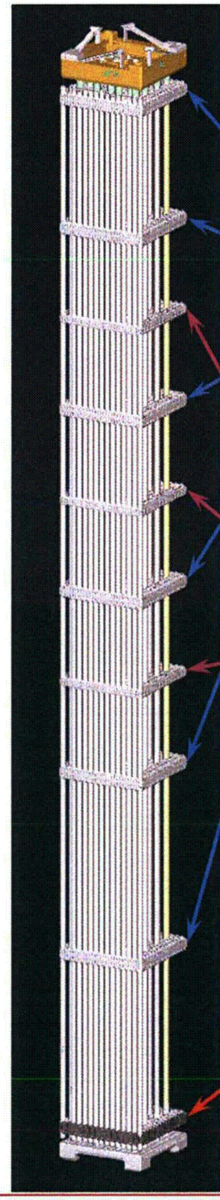
Overview of HTP Fuel Assembly

- **Hold-down Springs**
  - *W – Leaf Springs*
  - *CE – 5 Coil Springs with Reaction Plate*
  - *B&W – Cruciform*
- **Removable Upper End Fitting**
  - *"Quick Disconnect"*
- **Fuel Rods**
- **Guide Tube**
- **Instrument Tube**
- **FUELGUARD Lower End Fitting**



- **HTP Grids**
- **IFM Grids (Optional)**
- **Alloy 718 Lower HMP Grid**

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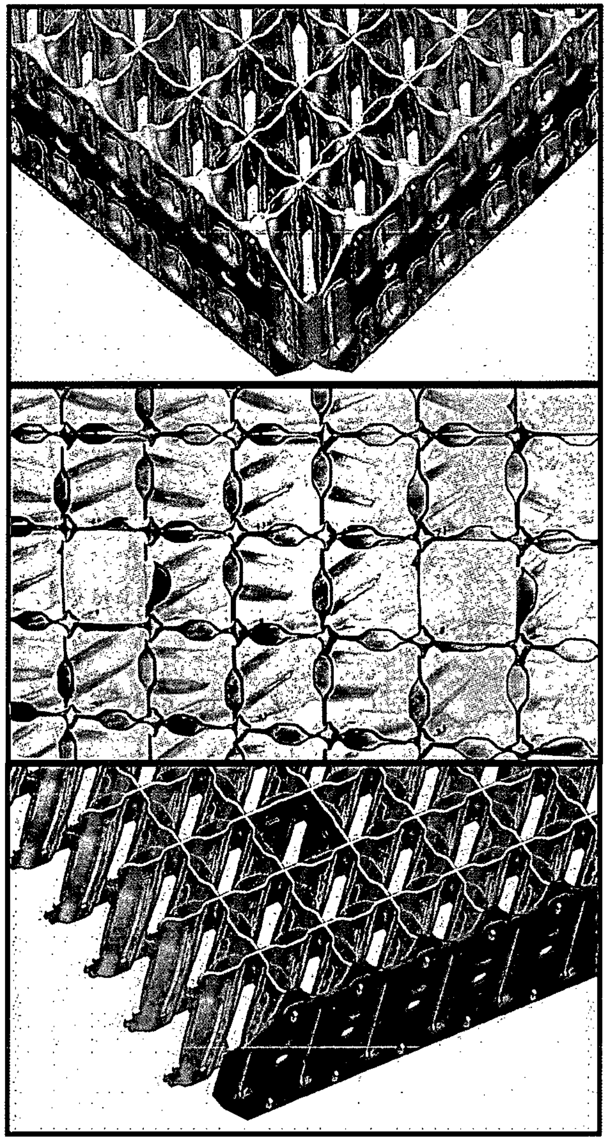
HTP Spacer Grid Design Concept

[ ]

- ***Balanced Stiffness and Damping Characteristics***
- ***Highly Effective Energy Dissipation***
- ***"Dual Line Contact" Rod Support System***
- ***Robust Construction***
- ***Low Flow Resistance***
- ***Curved Flow Channels for Flow Mixing***

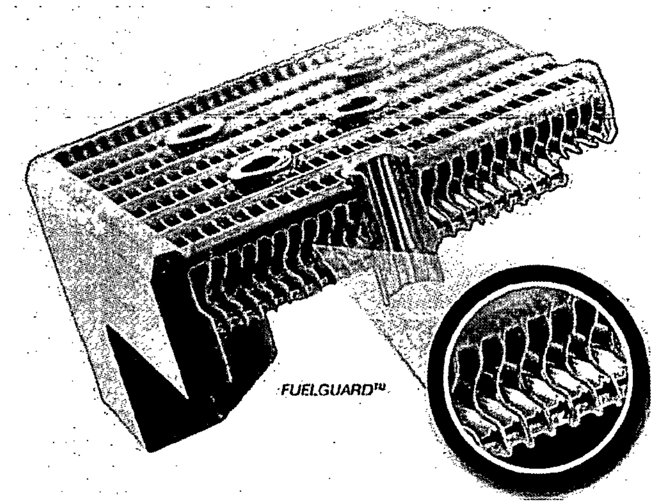
Design Features – Spacer Grids

> HTP Grid
  - M5 (Zirc-4) Material
  - Curved Flow Channels
  - Welded to Guide Tubes
> IFM Grid
  - Added Thermal Performance
  - M5 (Zirc-4) Material
  - Angled Flow Channels
  - Welded to Guide Tubes
> HMP End Grid
  - Lower Grid Location
  - Alloy 718 Material
  - Straight Flow Channels
  - Capture Rings

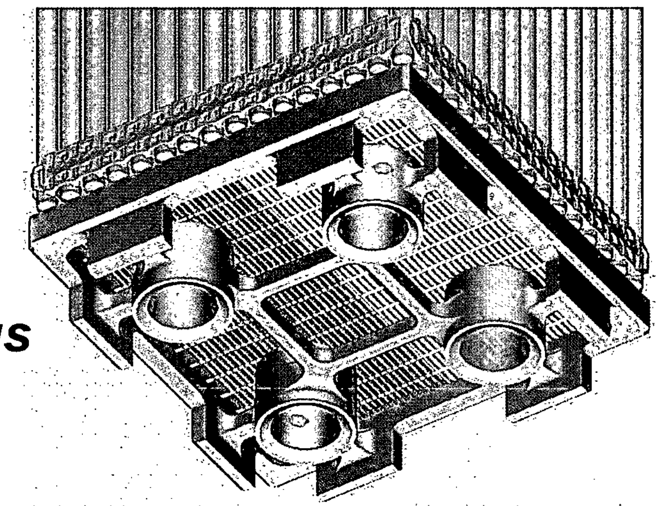


Design Features – FUELGUARD

> **FUELGUARD Design**
- *No direct line of sight*
- *Effectively filters debris*
- *Low pressure drop*
- *Reduction of inlet turbulence*



> **FUELGUARD Effectiveness**
- *No debris passing through FUELGUARD has caused failures*
- *Over 6,300 PWR assemblies delivered with FUELGUARD debris protection*



> **Design Versatility**
- *Same concept applied to various PWR Designs and BWRs*

Operating Experience – HTP Fuel Assemblies

> Over 6,800 HTP Fuel Assemblies loaded into 41 plants

> Maximum achieved fuel assembly burn-up of 65 GWd/mtU

> Worldwide – Zero known Fretting Failures at HTP Spacer Positions

- 18 Years of flawless operation (1,594,379 Fuel Rods)

> Proven in a wide range of design variants and flow conditions

- CE 14x14 and 15x15 (First in 1988)
- Siemens KWU 15x15, 16x16 and 18x18 (First in 1989)
- Framatome ANP 17x17 (First in 1993)
- Westinghouse 14x14, 15x15 and 17x17 (First in 1994)
- B&W 15x15 (First in 2003)
- Currently Adapting for CE 16x16 HTP Design
- Planned for EPR 14' 17x17 Design

Planned Enhancements – Material and Structure

Outline of Presentation

> Advanced Mark-BW Design Review

> Mark-B Design Review

> HTP Design Review

> **New PWR Fuel Design Development**

Product Development Process
Evolutionary and Revolutionary

The GAIA Project – Innovation for the Future

The GAIA Project – Innovation Process

Conclusion

Fuel Product Designs continue to evolve:

> Meet operational needs

> Increase fuel performance and reliability

> Increase design margins and safety

Questions?

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PWR Core Engineering Methods

Thomas L. Lotz

Manager, PWR Core Engineering

Current Code Systems – Global Diversity

	Lynchburg	Richland	Paris/Lyon	Erlangen
Cross-Section	CASMO-3	CASMO-3	APOLLO-2	CASMO-3
Neutronic Simulator	NEMO	PRISM	SMART	PRISM
Kinetic Simulator	NEMO-K	---	SMART-K	PANBOX
Thermal-Hydraulics	LYNXT	XCOBRA-IIIC	FLICA-IIIF	COBRA-3CP
Fuel Rod	TACO3	RODEX2A	COPERNIC	CARO

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The Future – and Beyond!

APOLLO2-A / ARTEMIS Development

APOLLO2-A / ARTEMIS Features

[ ]

APOLLO2-A / ARTEMIS Features (cont.)

Benefits of APOLLO2-A / ARTEMIS System

COPERNIC3 Background

- COPERNIC development began in 1994
- Lyon and Lynchburg joint effort
- Submitted in September 1999
- Siemens/Framatome Joint Venture in 2001
- COPERNIC reviewed and approved by NRC
  - SER for UO2 and UO2-Gd2O3 in June 2002
  - SER for MOX in January 2004
- Limited implementation due to Joint Venture
- New development needed to meet global needs

COPERNIC3 Development

Reactivity Insertion Accident Analysis

- Topical Report to be submitted by Dec. 2007
  - General Method for Application
- Report Application will be specific to US EPR
- Report will address RIA criteria and justification
- Methology will include:
  - NEMO-K 3D kinetics
  - Improved LYNXT model
  - COPERNIC fuel properties
- RIA Application Report to follow for other reactor types.

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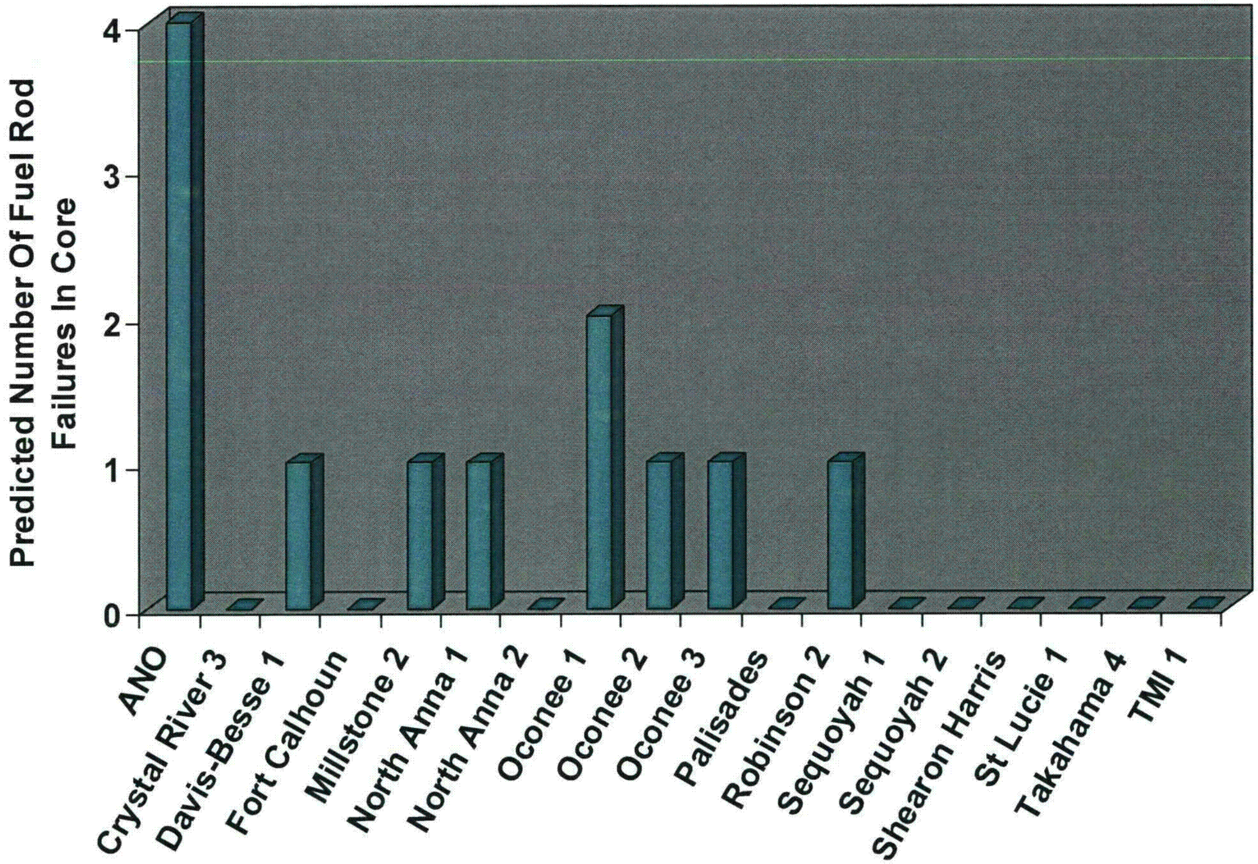
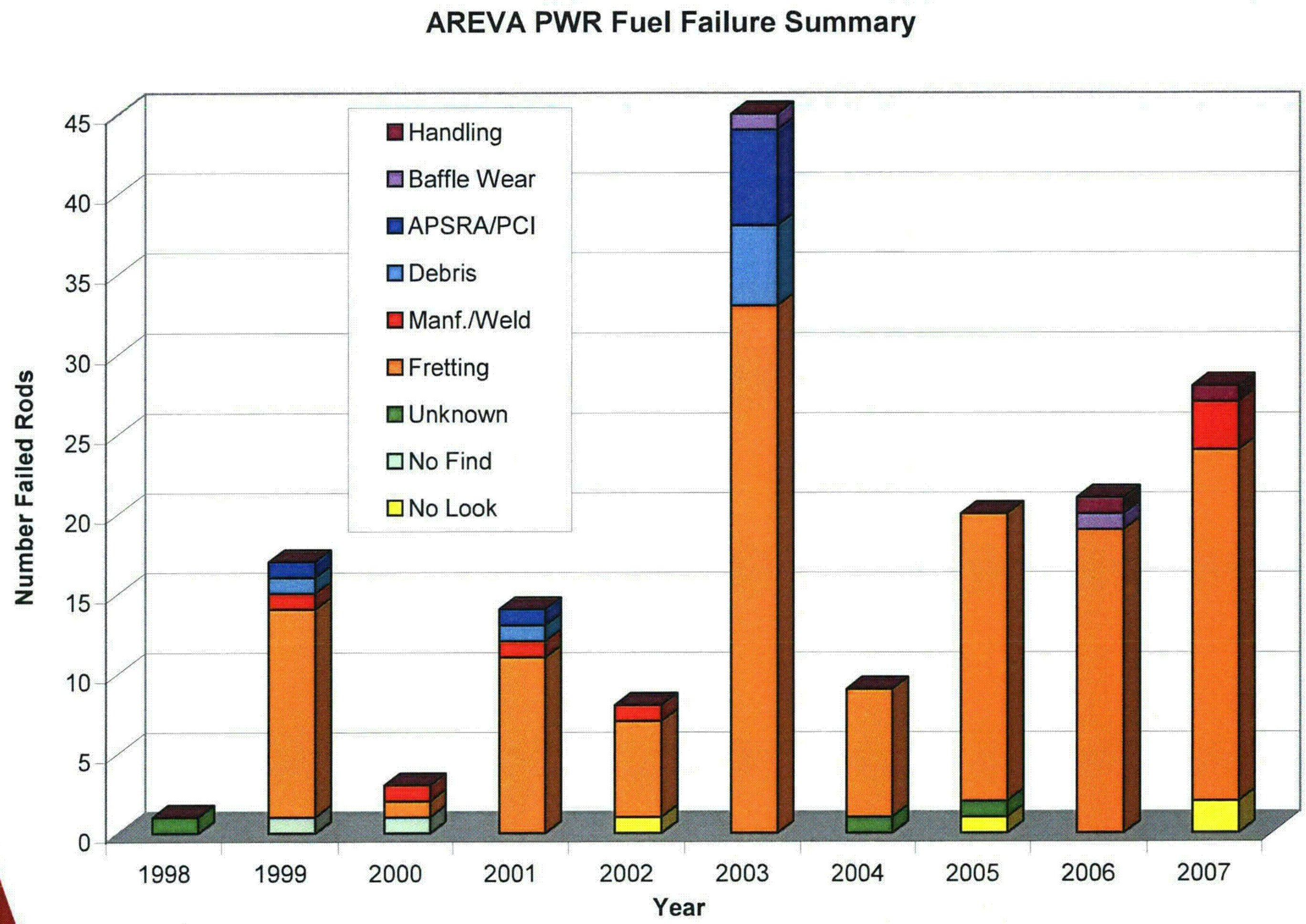
PWR Fuel Performance Experience

John T. Willse
Manager, Fuel Reliability and Performance

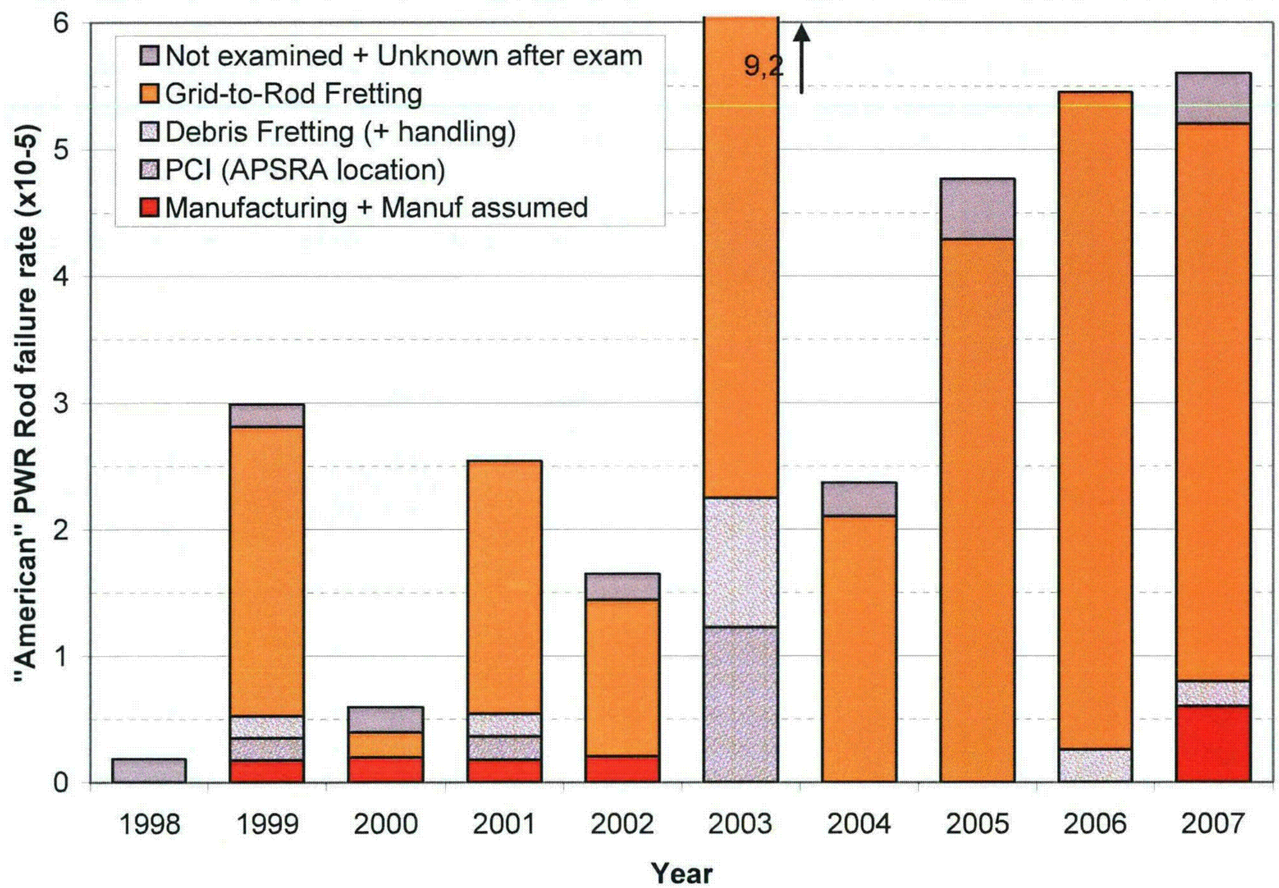
AREVA NP PWR Fuel Performance Status As Of 03/18/08



PWR Number of Failed Rods by Cause Past 10 years



PWR Ten Year Failure Rate



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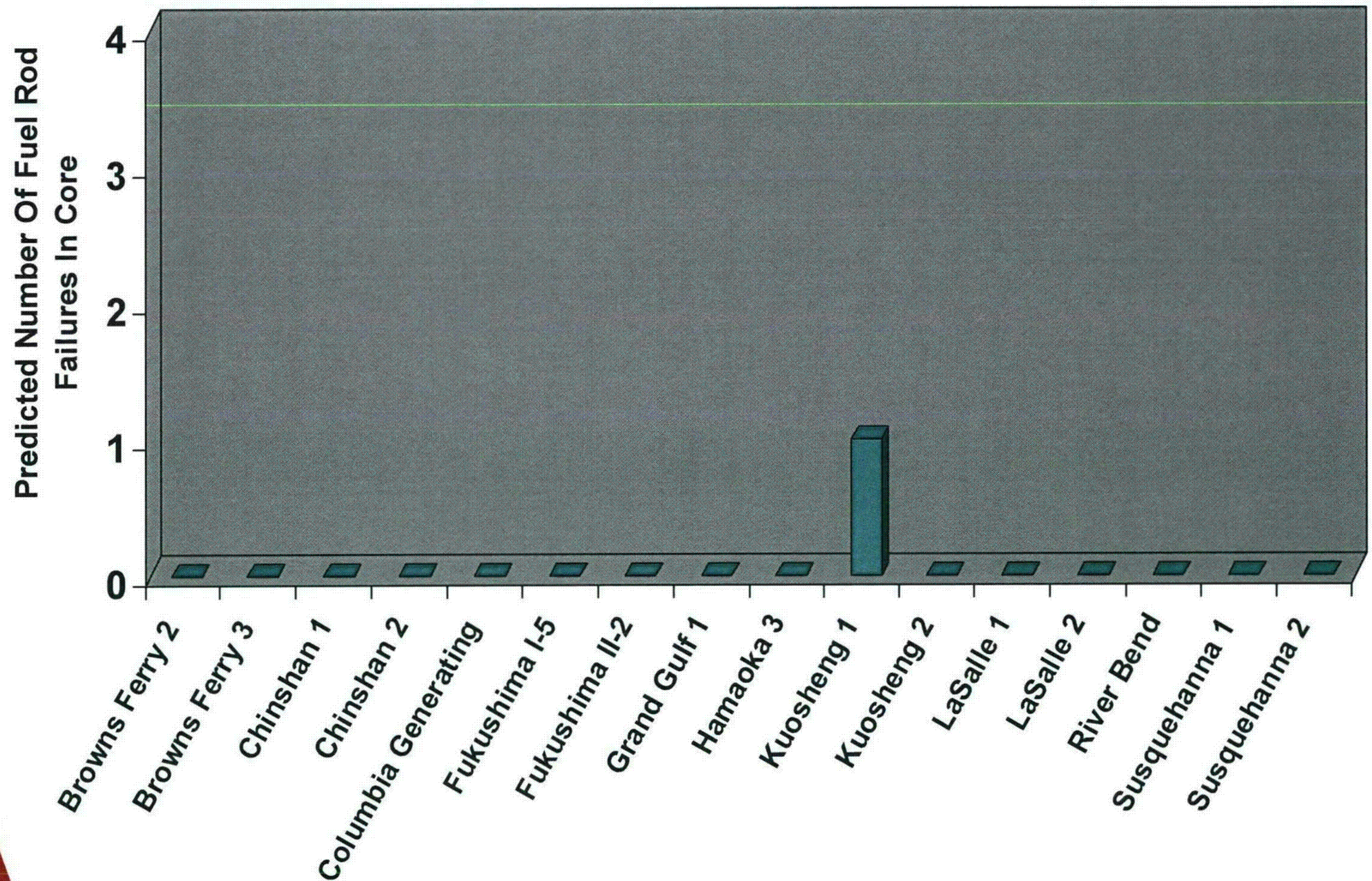
Predominant Failure Mechanism Is Spacer Grid Fretting Wear

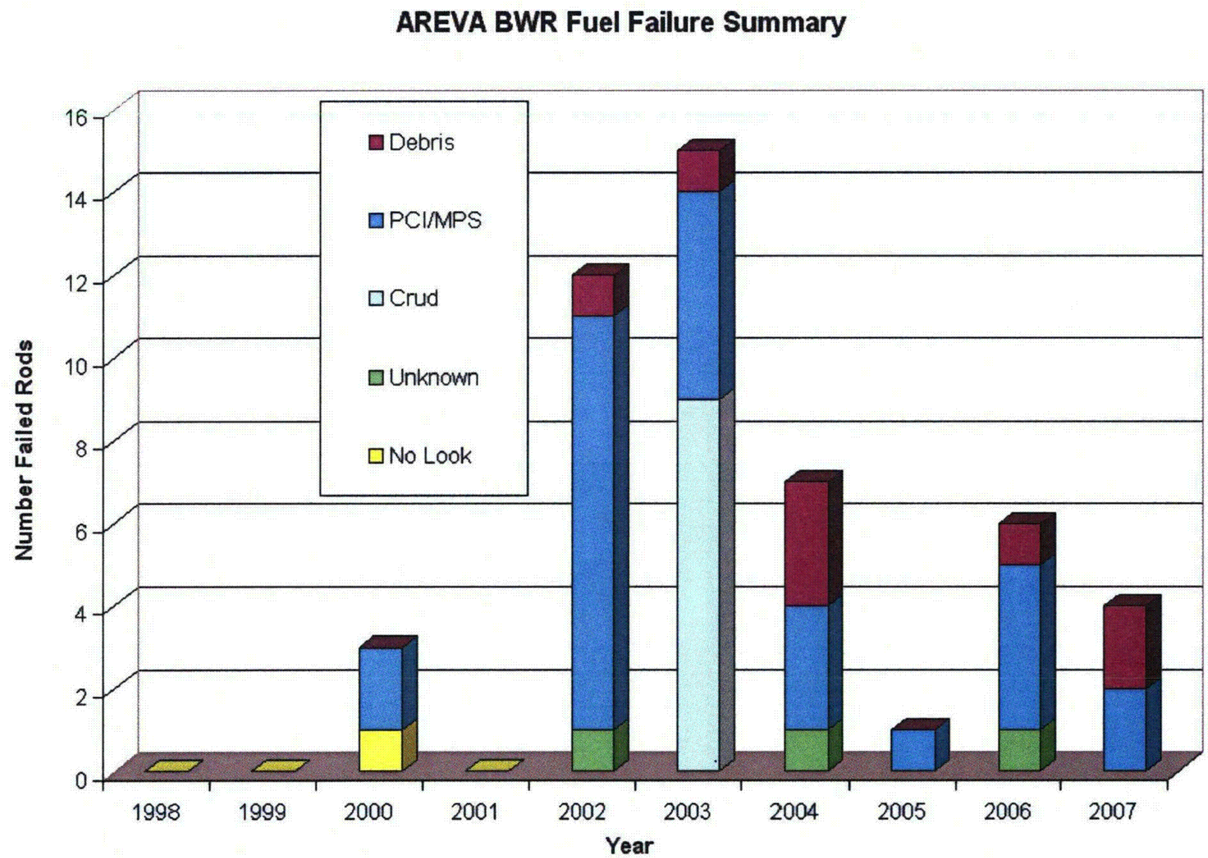
> **Failure should be eliminated by completion of the transition to HTP fuel assembly design**
  - ANO – Completed next cycle
  - Davis-Besse - Completed next cycle
  - Millstone 2 – 2 more cycles
  - Oconee 1 – 3 more cycles
  - Oconee 2, & 3 – 2 more cycles each
  - TMI – 1 more cycles

> **Failures currently under irradiation at Davis-Besse, Oconee 3, and Robinson still need to be investigated**

AREVA NP BWR Fuel Performance Status As Of 03/18/08



BWR Number of Failed Rods by Cause Past 10 Years



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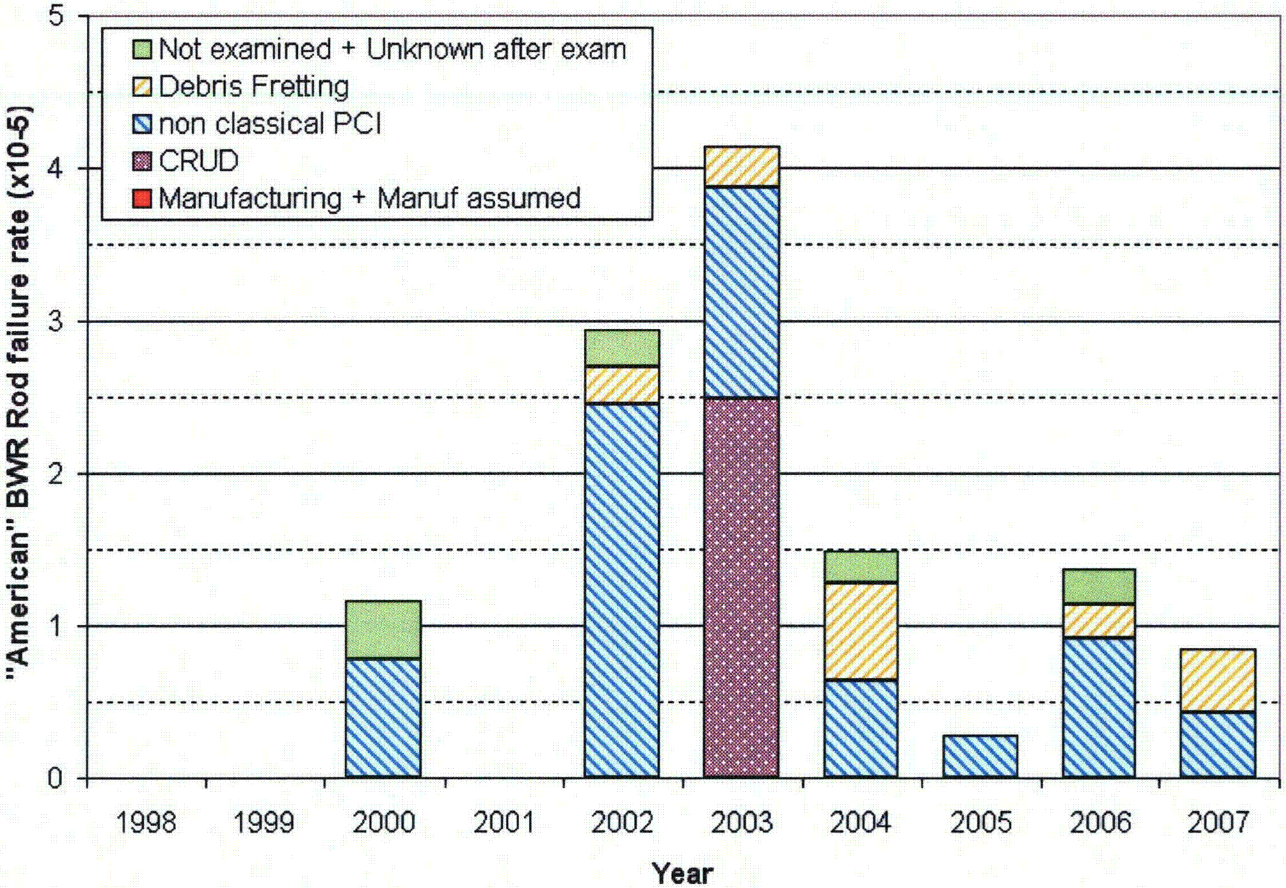
BWR Ten Year Failure Rate



BWR And PWR Performance Are Connected

- Same source of pellets
- Same manufacturing techniques at different locations
- For the last four years debris and PCI assisted by missing pellet surface has been the predominant failure mechanism
- No PCI failures in any fuel rods manufactured after the implementation of the corrective measures to eliminate this failure mechanism

International Fuel Performance

> No defined issues have been identified
> There is a slight increase in first cycle failures both in the US and Europe in PWRs
> Most first cycle failures are from debris or failures associated with obsolete manufacturing processes
> First cycle failures are still a concern that is being followed

Millstone-2 Cycle 17 Fretting Failures and Design Resolution

Key Messages: Condition Understood and Implementing Proven Design Fix

> CE14x14 plants have particularly high cross-flows near the baffle at the bottom and top regions of the core

> The Millstone-2 fuel assembly design has been unique from the other CE14x14 plants – bottom grid design

> Combination of relaxed grid cells, clad diametral creep, and harsh flow conditions allowed rods to spin – resulting in failures

> Implementation of mature Inconel HMP™ grid in the lowermost position precludes rotation and failure

Inconel HMP lower grid with improved relaxation properties maintains rod contact.

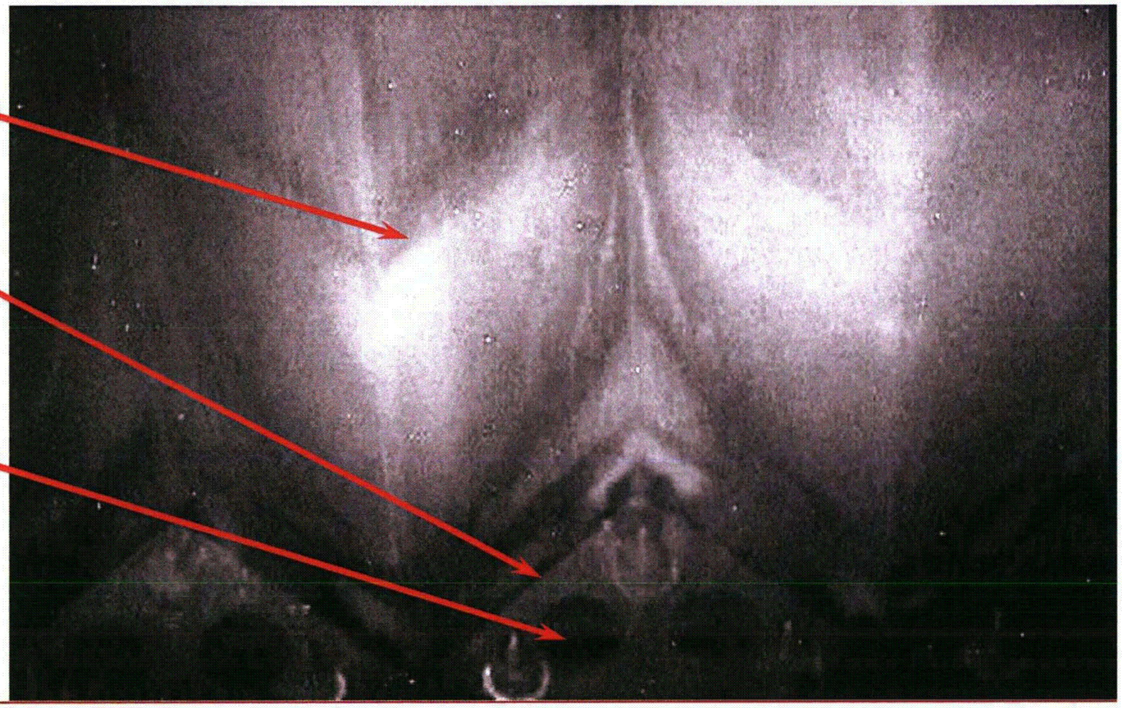
History: High Cross-Flow Environment in CE14x14 Reactors

- Former non-HTP™ assemblies have experience random fretting failures on core periphery
- CE14x14 reactors exhibit high cross-flow behavior in lower and upper core regions

High cross-flow impinging baffle wall

Larger gap between assembly and baffle

Inlet & outlet core plate holes interior to the assemblies



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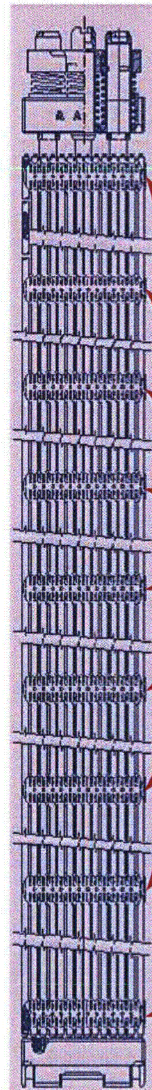
History: CE14x14 HTP Fuel Assembly at Millstone-2

- **Upper End Fitting**
  - *Quick Disconnect*
- **176 Fuel Rods**
- **4 Corner Guide Tubes**
- **1 Center Guide Tube**
- **FUELGUARD™ Lower End Fitting**

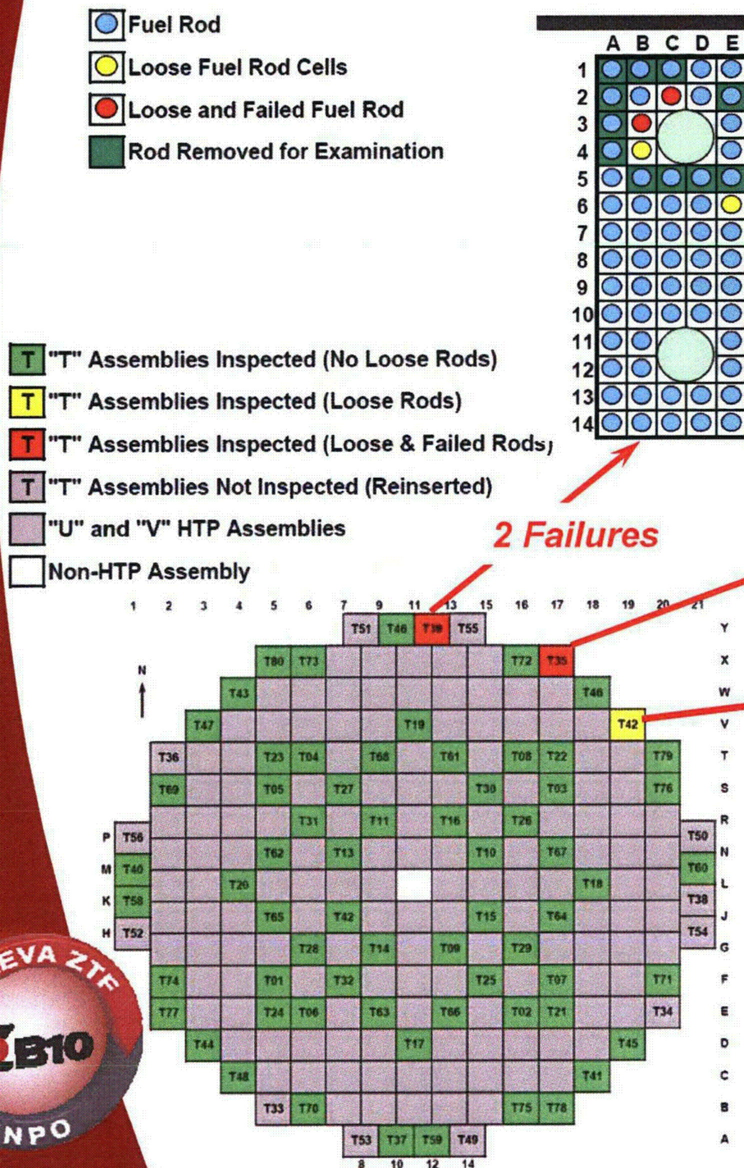


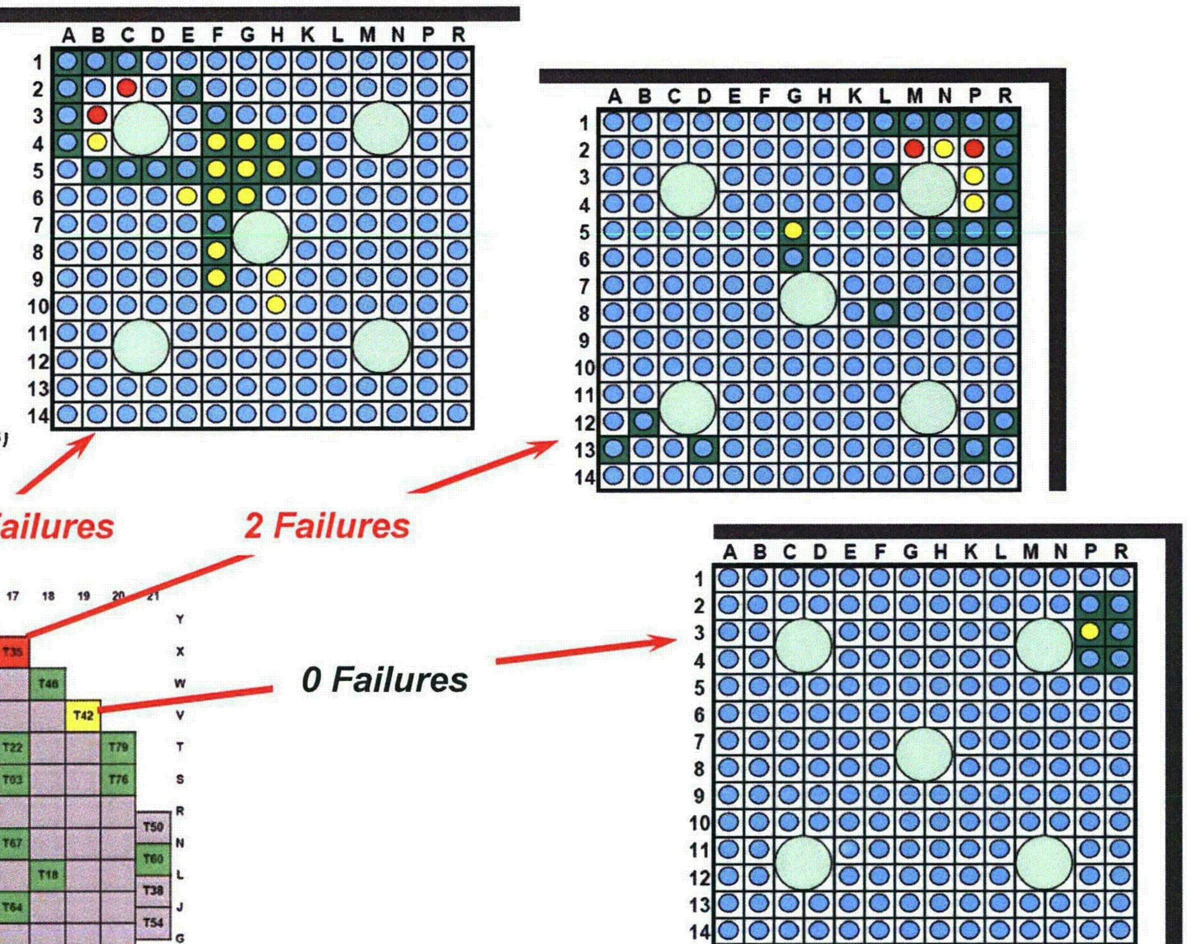
The Millstone-2 design was unique from all other CE14

HTP Grids (8x)

HTP Lower Grid (unlike other CE14 designs)

History: Millstone-2 Cycle 17 Failures





- *Total 68 "T" assemblies inspected*
- *2 failed "T" assemblies (2 rods each)*
- *Loose rods – precursor (1 additional assembly)*

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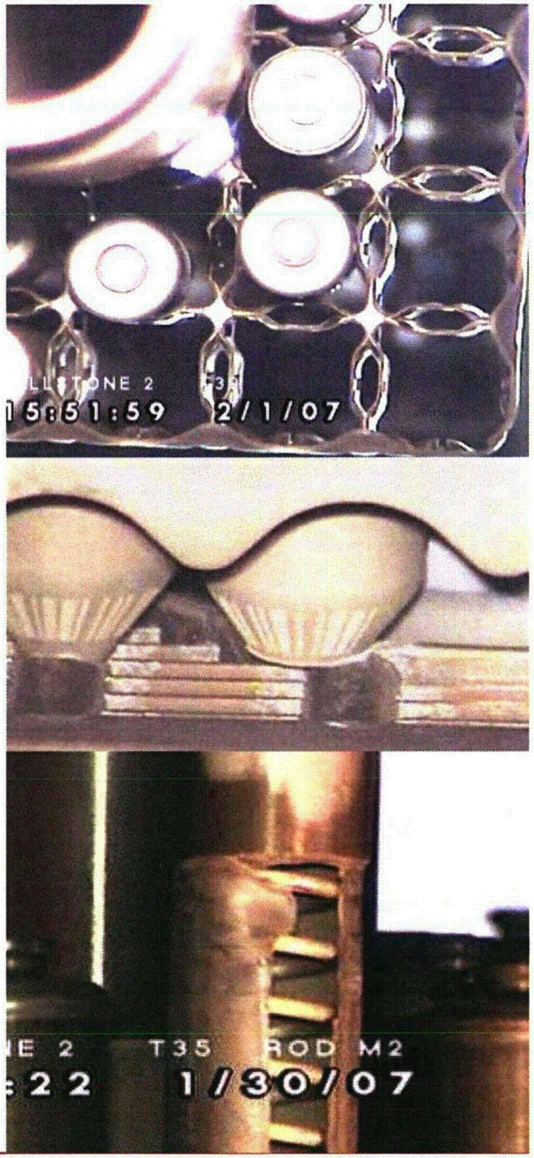
Proprietary

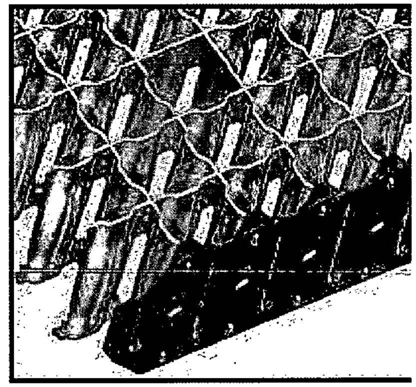
History: Progression to Failure

- During 1st and 2nd cycles, Zircaloy grid springs relax
- In low power 3rd cycle, gap forms in the upper grid locations (long lower end cap prevents gap at bottom)
- Cross-flow causes rod vibration, grid wear, and gap in bottom grid
- With gaps at all elevations, rod spins due to hydraulic forces and wears grids and rod eventually to failure
- Spinning necessary to get fretting failure with HTP spacer

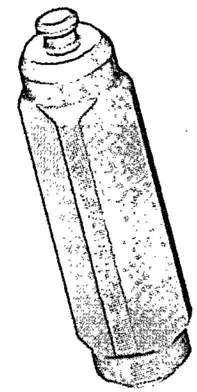


AREVA ZTF
ZB10
INPO

Status: Mitigating and Preventive Actions



- Root Cause Analysis – completed
- Estimate one failure in current cycle
- Inconel (Alloy 718) HMP lower grid scheduled for Cycle 19 insertion (spring 2008)
  - Same HMP grid used at St. Lucie-1 and nearly identical to Ft. Calhoun
  - HMP grid design is consistent for all designs – scaled for array
- Finalizing a mitigating solution for resident fuel
  - Focus on high potential failure areas
  - Square upper end cap developed



- Confirmatory PIE programs at other CE Plants

Status – Extent of Conditions

> **B&W15:** Mark-B-HTP has lower HMP, Mark-B11 has Inconel end grids

> **W15 & W17:** All designs contain Inconel lower grid spring designs

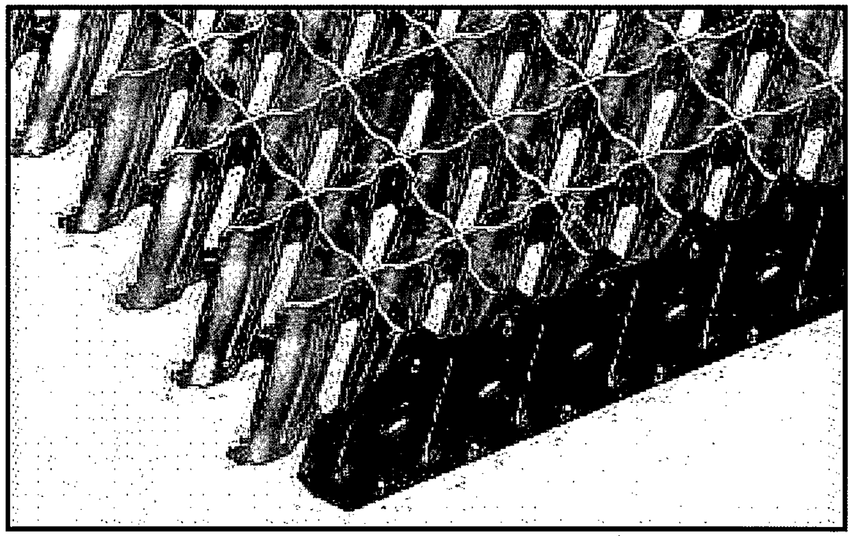
> **CE14:** All other current designs utilize Inconel HMP (reinsertion of Calvert Cliffs LFAs limited to non-baffle locations)

> **CE15:** Lower Zirc-HTP
- Less severe flow conditions
- Over 4 cycles of successful operation
- HMP available, but not required

> **CE16:** LUA design utilizes Inconel HMP (fall 2008)

Conclusions – Proven Design Solutions

> Failure mechanism is understood
> AREVA has a proven and mature solution – the Inconel HMP lower end grid



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Palisades 1 Cycle 19 Fuel Failures Root Cause Investigation Update

Background

- Level 2 Condition report in late September 2007 at time of fuel examination
  - An Apparent Cause team with representatives from Entergy, AREVA, and EPRI identified the most likely causes of failure:
    - Massive internal contamination from hydrogenous or halogen material
    - Contamination leading to lack of bonding in the end cap welds
- Condition report elevated to Level 1 in early November 2007 when ACA unable to identify cause
  - A Root Cause team was formed to evaluate the manufacturing processes for end caps, plenum springs, pellets, cladding, and rod loading
    - Identify credible sources of contamination
    - Develop corrective actions to prevent recurrence

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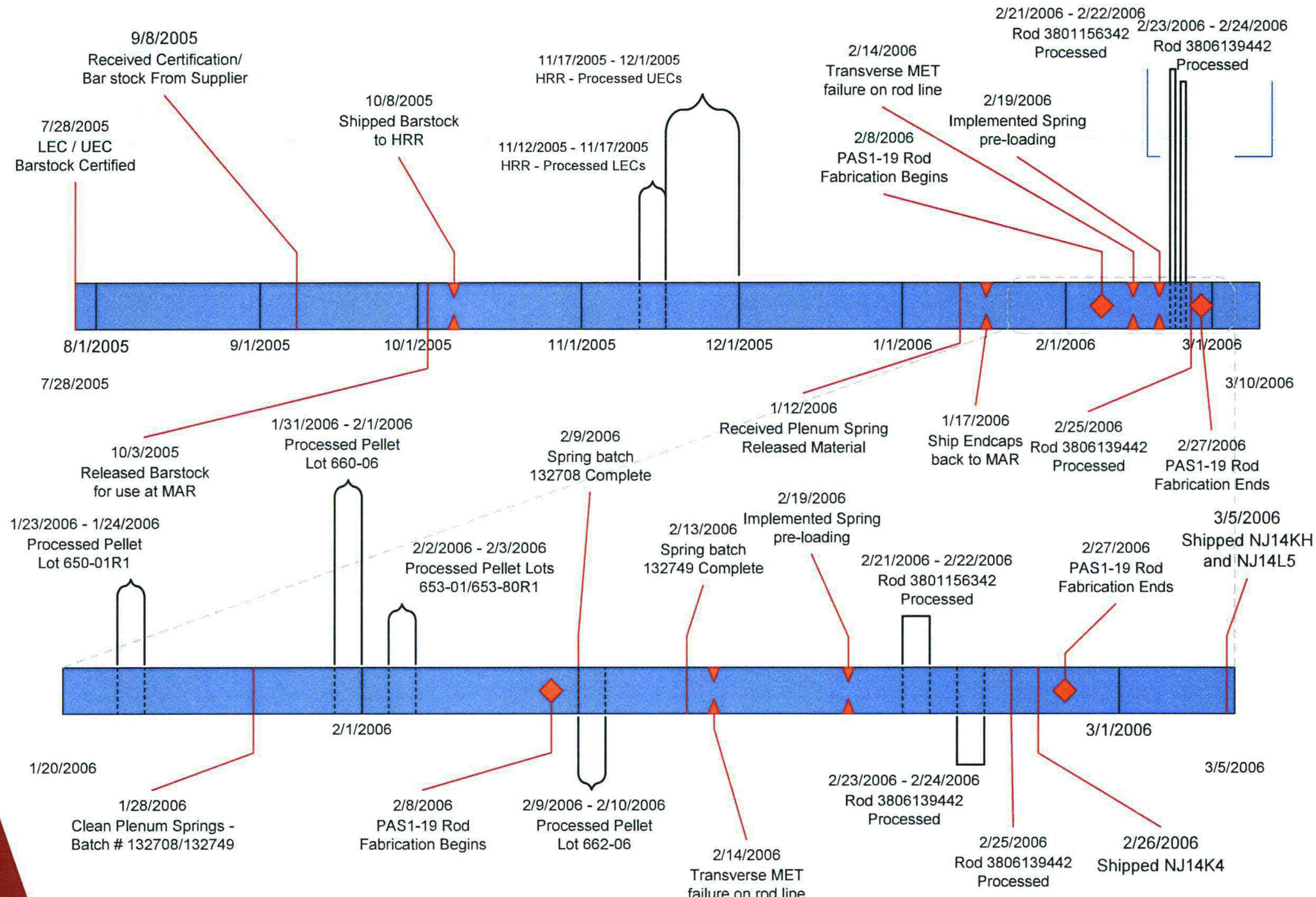
Timeline of Events



Unique Aspects of this Contract

> 1st Palisades contract built at MAR
  - End caps made and cleaned at HRR – barstock sent from MAR to HRR

> Transverse MET failure of weld sample due to uranium contamination in the bond line

> Pre-set of plenum springs
  - Stainless steel plate used to pre-compress springs at rod loading

> Power gradient due to unlatched control blade at startup
  - Localized effect on power shape, not in the vicinity of failed rods

No evidence to suggest that these events are related to the fuel failures

Investigation Status

> ACA and RCA investigations have not led to a "smoking gun"

> A number of potential causes can be eliminated because impossible or highly unlikely:

- Fuel / Core shroud interface
- Clad collapse
- Water chemistry control
- Clad vulnerability to corrosion
- Handling damage
- Pellet clad mechanical interaction : PCMI, classical/non-classical PCI, hydride assisted
- Debris
- Accelerated corrosion of end cap welds
- Undetected cladding flaw
- Power flux

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Investigation Status (cont.)

> *Other potential causes :*

- *Primary hydriding due to contaminants inside the rod : unlikely based on substances found in the manufacturing areas*
- *Flaw in end-cap material (stringer) : unlikely based on ingot manufacturing and inspection records*
- *Lack of bonding within the end-cap weld*

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Team's Recommendations

> *Team recommends further testing of failed rods to identify (or eliminate) potential failure causes to facilitate development of corrective actions*
  - *Hot Cell or poolside pressurized test of end segments would reveal any non-bonded weld regions*
  - *Would also reveal any end cap stringers, if present (low probability as failure cause)*

AREVA evaluating this recommendation in relation with Entergy

Team's Recommendations (cont.)

> Team recommends experimental weld samples and burst tests to expand knowledge base of USW contamination resistance or susceptibility
  - Some results exist, indicate that spring wire lubricant, detergent, and uranium can interfere with bonding.
  - Copper, other contaminants do not affect weld integrity.
  - Stainless Steel/Inconel – used for spring pre-set on this contract should be tested (spring pre-set no longer done with new MAR upper-end welder)

> Although not believed to be related to the PAL fuel failures, HRR and MAR will perform assessments of processing areas with regard to housekeeping and material control

Fuel Crud Deposits at Davis-Besse

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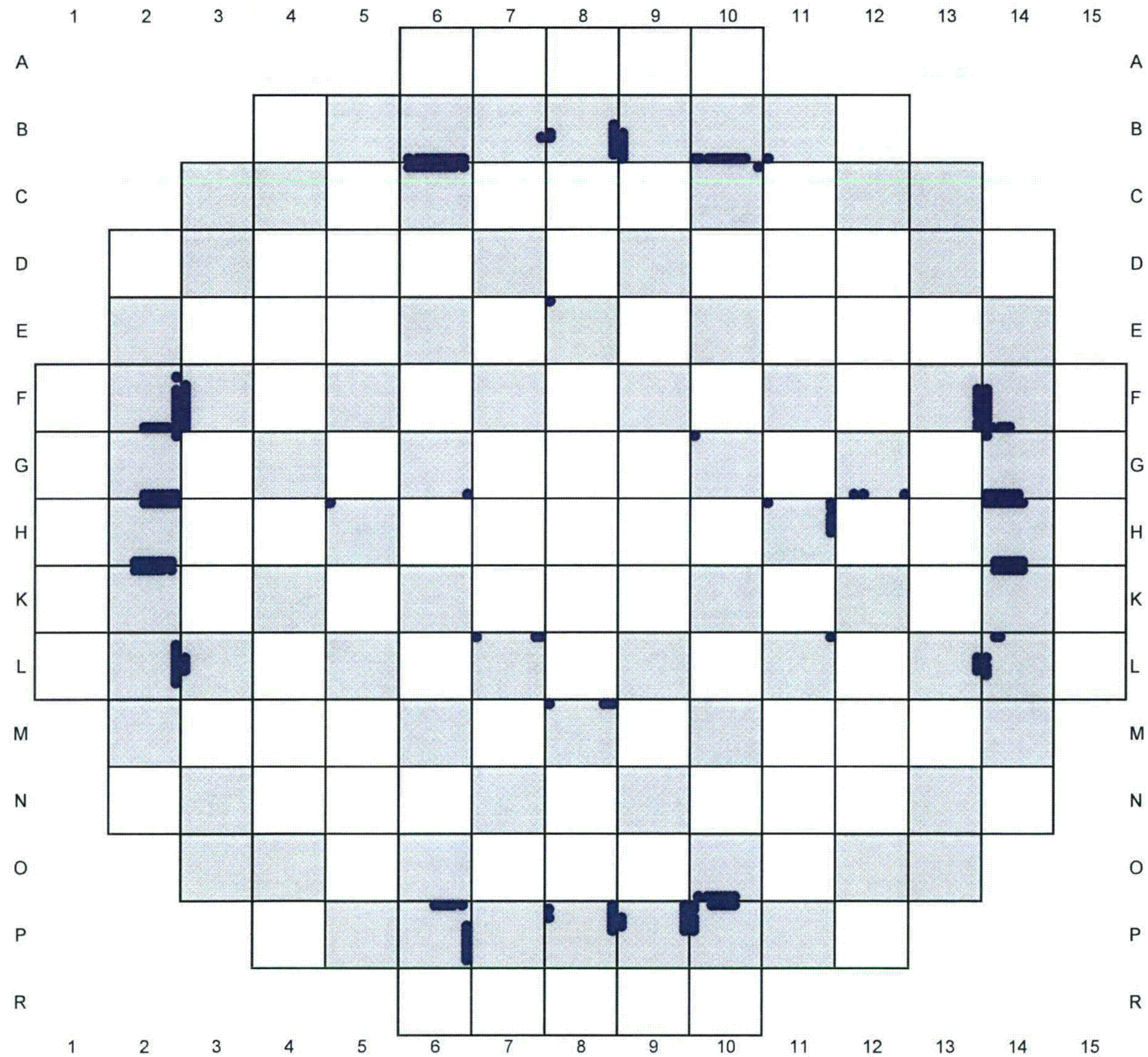
Observations during Cycle 15 RFO

- 37 Mark-B-HTP™ fuel assemblies were observed with crud deposits on the perimeter rods
- Most fuel rods observed with elevated levels of crud deposits operated adjacent to other fresh fuel assemblies during Cycle 15
- The crud was primarily noted between the 2nd and 3rd spacer grids from the top of the assemblies, with lesser amounts sometimes visible between the 3rd and 4th grids from the top

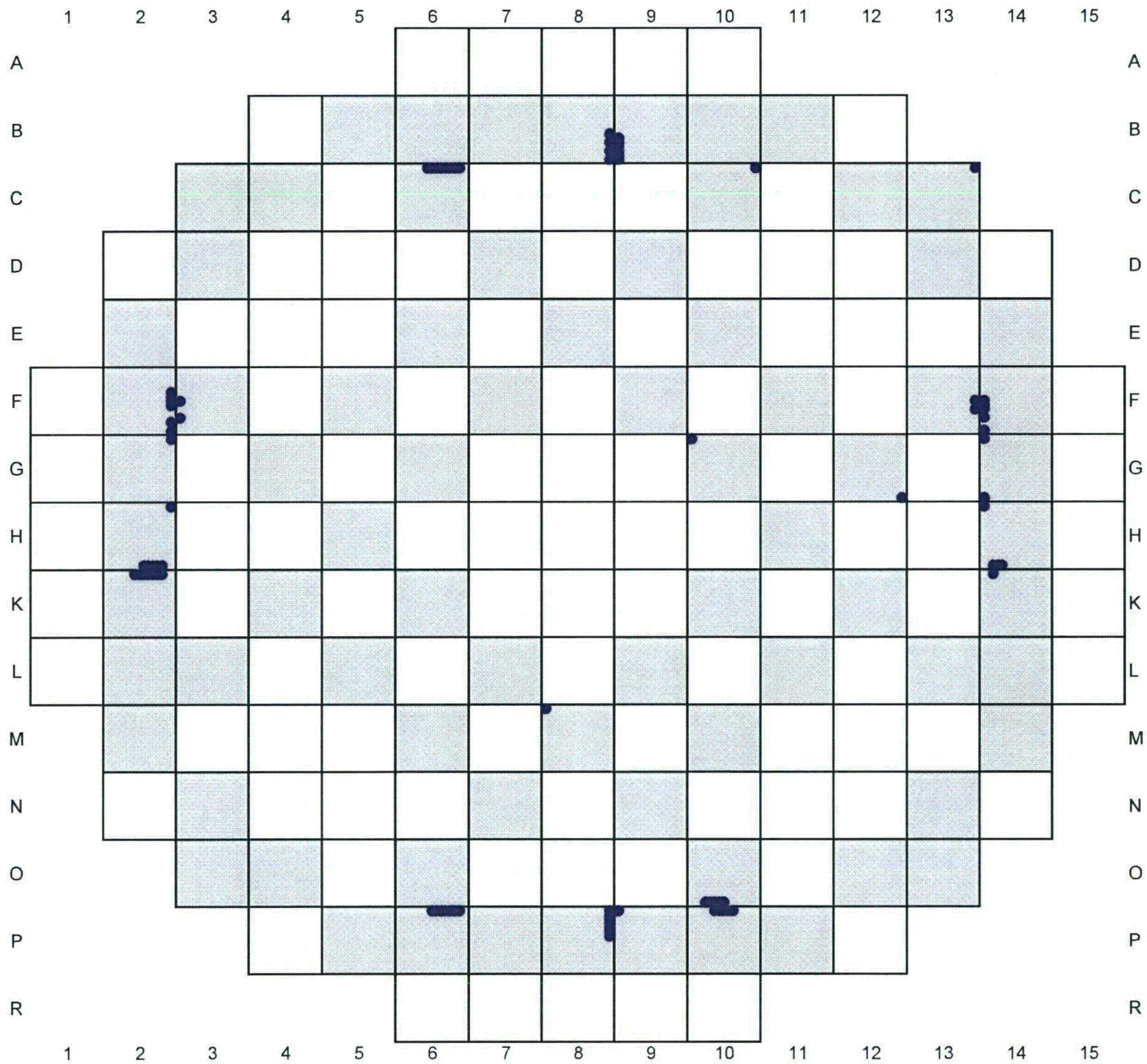
Observations during 15 RFO

SPAN: 2



Observations during Cycle 15 RFO

SPAN: 3



Observations during 15 RFO

> Three rods were pulled from a "limiting" fuel assembly and inspected for waterside oxide layer thickness and loss of cross-sectional area

- No loss of cross-sectional area measured
- Maximum measured oxide thickness – which included some contribution from crud - was approximately 40 micrometers

> Based on the fuel inspection for the crud deposits, all of the Mark-B-HTP fuel assemblies were determined to be acceptable for insertion into Cycle 16

What's Next?

> Actions being taken by AREVA NP

- *Reviewing plant RCS chemistry records to determine any potential source for the elevated crud deposits on the fuel cladding*
- *Performing thermal-hydraulic modeling of the Cycle 15 core to determine any potential causes of the crud condition*

Conclusion

- The completion of the transition to the new more robust designs will improve fuel performance significantly
- Not all transitions will be completed by 2010
- Some legacy failure mechanisms will continue for a few years
- Fuel performance is going to improve

BWR Fuel and Hardware Testing Programs

Rose Montgomery
PIE Coordinator,
Fuel Mechanical & Structural Design

BWR Objectives

> Continued confirmation of existing and advanced design performance

> Purpose of the latest PIE data is to specifically support:

- Fuel Channel bow, bulge, shadow corrosion
- Water channel length & hydrogen uptake
- Reduction in the uncertainty application in RODEX creep collapse model for SRA cladding
- Implementation of RXA cladding
- Kobe channel performance
- High burnup SRA cladding performance
- Demonstrate Pambeouf cladding performance
- Support possible limit modifications for RIA

BWR Test Assembly Programs

> Atrium 10 XM (LaSalle 2)
  - RXA cladding
  - Cr-doped pellets

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2006-2007 BWR Poolside PIEs excluding channel bow exams

> *22 GWd/mtU Atrium 10 w/LTP clad (Columbia Generating Station)*
  - *Fuel assembly visual examination*
  - *Crud sampling*

> *19 to 40 GWd/mtU Atrium 10A (Kuosheng-1)*
  - *Fuel assembly visual examination*

> *19 to 40 GWd/mtU Atrium 10A (Brown's Ferry 2 & 3)*
  - *Fuel assembly visual examination*
  - *Oxide measurements*

AREVA RXA BWR Experience Summary

[ ]

AREVA RXA BWR Experience Summary (cont.)

[ ]

Fuel Channel Performance

Mark H. Smith
BWR Mechanical Analysis Engineer

BWR Fuel Channel Bow Issue – 2008 Update

- A brief overview of the AREVA fuel channel distortion issue
- Recent operating events
- Update on fuel channel poolside measurement exams
- Cell friction calculations
- Summary

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview

> Timeline

- ***Starting in 2002, AREVA develops fuel channel measurement equipment as part of an EPRI Fuel Reliability Program.***
- ***March 2003 - GNF reports new bow phenomena "affecting thick/thin" fuel channels in BWR/6 reactors***
  - ***Bow caused by shadow corrosion***
  - ***No signs of cell friction issues observed with AREVA fuel channels (yet)***
- ***May 2004 - AREVA fuel channel measurements:***
  - ***May 2004 - Susquehanna Unit 1***
  - ***June 2004 - Quad Cities Unit 2***
  - ***Channel bow appears to be normal (EPRI report 1008097)***

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview (cont.)

> Timeline

- May 2005 – PPL reports signs of control rod friction in cells containing AREVA fuel channels.
- September 2005 – GGNS discovers control rod friction at Grand Gulf during EOC 14 shutdown.
  - AREVA measures fuel channels at Grand Gulf. Several channels exhibit unexpectedly high bow.
- October 2005 – PPL shuts Susquehanna Unit 1 down (MOC 14) for fuel channel replacement and examination with 41 STS (slow-to-settle) and 4 INOP control rods.

> AREVA has taken a number of actions since this time.

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview (cont.)

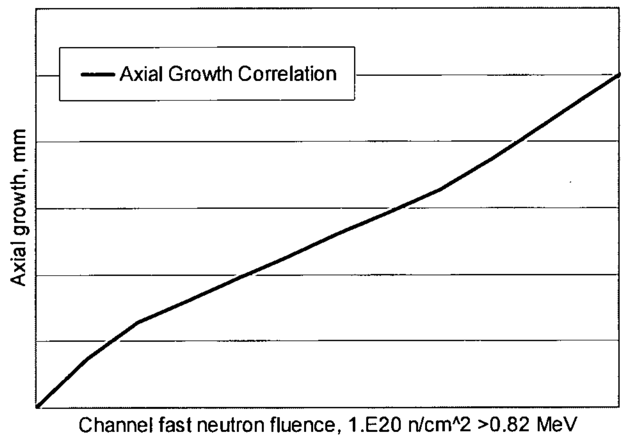
> ## *Culmination of events*

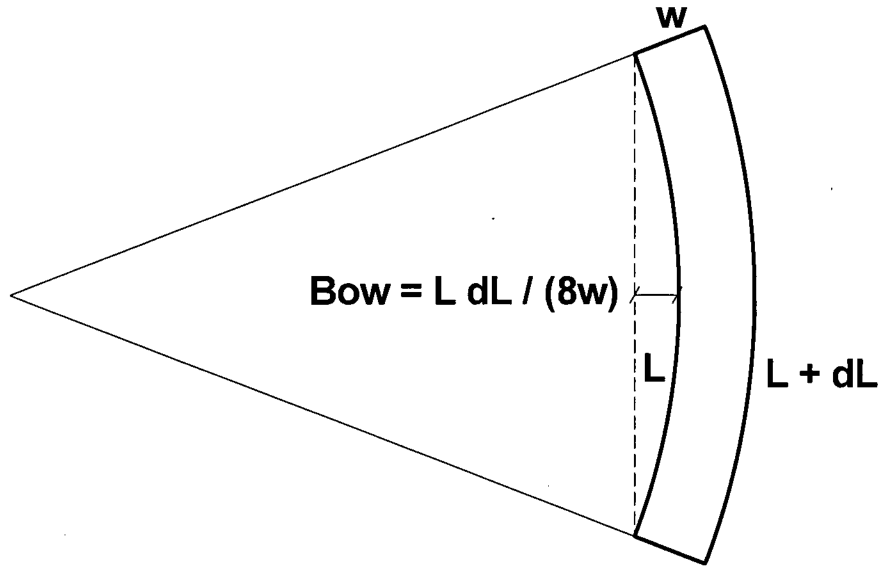
- ***AREVA has conducted 13 channel measurement campaigns on a total of 906 fuel channels at 7 reactors.***
- ***Surveillance guidelines were developed to monitor susceptible control cells for signs of control rod friction.***
- ***Material coupons were acquired from fuel channels at LaSalle Unit 1 in June 2006 and Susquehanna Units 1 and 2 in February 2007 for hot cell examination.***
- ***Improvements in analysis methods for predicting cell friction are under development.***
- ***Majority of utilities switched back to using Zircaloy-4.***

BWR Fuel Channel Bow Issue – 2008 Update A brief overview (cont.)

> Fuel channel bow

- *"Classic" bow is attributed to the differential growth between opposite sides of the fuel channel due to fast neutron fluence.*





- *Following this approach, bow would be nearly proportional to the fast fluence gradient.*

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview (cont.)

> ## *Fuel channel bow*

- ***Here is the Zry-4 measurement data as a function of fast fluence gradient.***

[ ]

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview (cont.)

> ## Fuel channel bow

- *Here is the added Zry-2 measurement data as a function of fast fluence gradient.*

BWR Fuel Channel Bow Issue – 2008 Update
A brief overview (cont.)

> *Fuel channel bow*

- *Abnormal bow ("shadow corrosion-induced")*
  - *Early-in-life control*
  - *Potential abnormal bow above a given exposure*

[ ]

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BWR Fuel Channel Bow Issue – 2008 Update
Control Rod Friction Surveillance

- ***Control rod friction surveillance guideline identifies control cells susceptible to control rod friction due to abnormal channel bow. The bow is correlated to:***
  - ***Early life exposure to the control blade***
  - ***Abnormal bow doesn't occur until higher exposures***

BWR Fuel Channel Bow Issue – 2008 Update
Control Rod Friction Surveillance

> *Control rod friction surveillance*

- *Identifies susceptible cells for sampling by periodic settle-time testing*
- *If cell friction is identified:*
  - *Additional testing is done on the cell to monitor friction so operator action can be taken if the friction becomes too high.*
    - *Preserve adequate scram insertion time*
    - *Avoid undue scram loads on fuel (lift off) or internals*
    - *Satisfy TS requirements for control rod operability*
  - *Ensure that the occurrence of abnormal bow is properly taken into account in the SLMCPR analyses.*
    - *Consideration of abnormal bow statistics in analyses.*

BWR Fuel Channel Bow Issue – 2008 Update
Control Rod Friction Surveillance (cont.)

> Control rod friction surveillance

- *Utilities with C-lattice or S-lattice plants and AREVA Zry-2 fuel channels are following the surveillance guideline.*

[ ]

- *To date, control rod friction problems attributed to channel bow have occurred in the plants underlined in the list above. Blue font indicates plants currently experiencing problems.*

BWR Fuel Channel Bow Issue – 2008 Update Operating Events

> Recent operating events

- **OE25435 – Unexpected Indications of Channel Bow (Grand Gulf)**
  - Event date: August 22, 2007
  - Three control rods failed to settle following rod stroking in preparation for startup following a scram.
  - All three cells were not identified as susceptible according to the AREVA surveillance guideline.
  - The three cells are on the core periphery
- **Currently operating with four cells exhibiting friction that require additional surveillance**

BWR Fuel Channel Bow Issue – 2008 Update Operating Events (cont.)

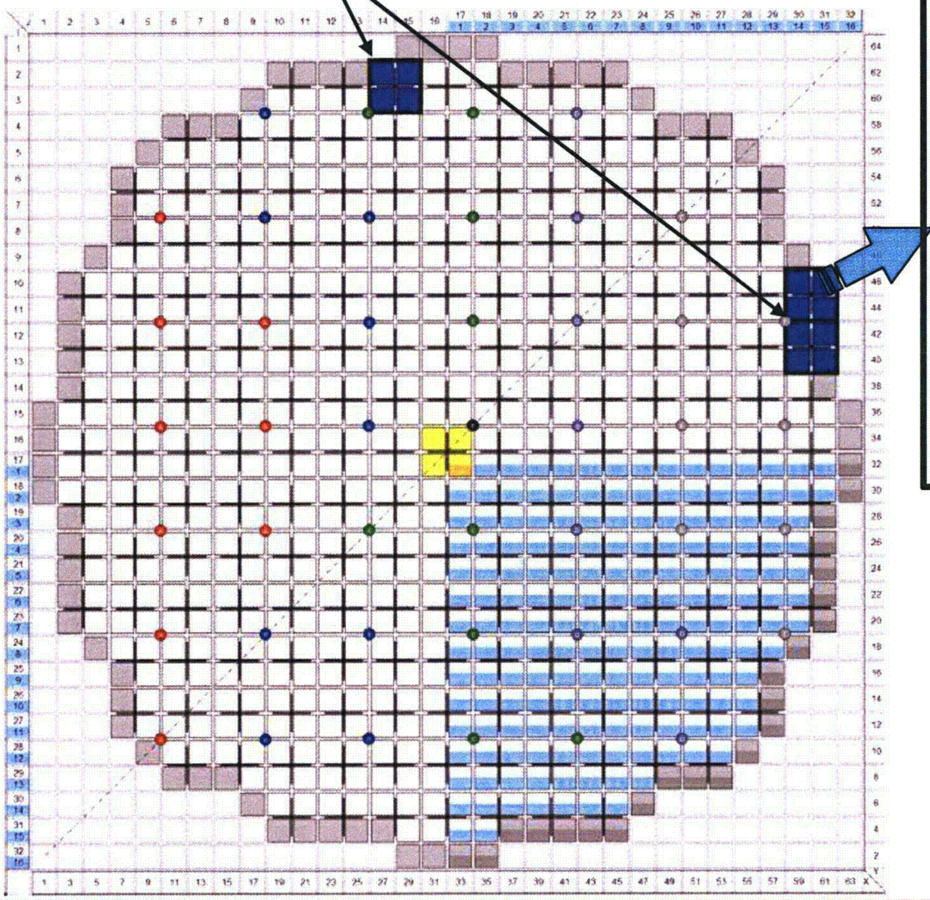
> Recent operating events

- OE25541 – Channel Distortion in Non-Susceptible Core Cells with High Exposure AREVA Bundles at LaSalle County Station
  - Event date: September 2, 2006 and September 9, 2007
  - Three control rods discovered at LaSalle Unit 1 exhibit friction – failed settle testing. Subsequent testing at Unit 2 revealed one control rod that was slow-to-settle.
  - All four cells were <u>not</u> identified as susceptible according to the AREVA surveillance guideline.
  - Four cells are on the core periphery
- Unit 1 EOC12 in February 2008:
  - Two peripheral cells declared INOP
  - Five other peripheral cells identified with friction
- Unit 2 Cycle 12 currently has 1 INOP and 1 STS

BWR Fuel Channel Bow Issue – 2008 Update Operating Events (cont.)

> **Case study – Grand Gulf peripheral cell friction**

3 no-settle cells



BWR Fuel Channel Bow Issue – 2008 Update
Operating Events (cont.)

> Case study – Grand Gulf peripheral cell friction

- Fluence gradient history of Assembly SPJ032

[ ]

BWR Fuel Channel Bow Issue – 2008 Update Operating Events (cont.)

> Case study – Grand Gulf peripheral cell friction

- Friction cell observations
  - Contains higher exposure fuel assemblies (4th of 18-month cycles)
  - Little early-in-life control (low EFID)
  - Accumulated fluence gradient is not high enough to explain the amount of bow to cause friction
  - Operation in a positive flux gradient location (core peripheral location with bow towards blade)
  - Fuel had operating on the core periphery in a prior cycle
  - Zry-2 fuel channels

> Other cells at Grand Gulf and LaSalle Units 1 and 2 share the same common characteristics as above.

BWR Fuel Channel Bow Issue – 2008 Update Operating Events (cont.)

> ## Interim control rod friction surveillance guideline

- AREVA issued a new interim surveillance guideline to address the two Operating Events:
  - Bow does not appear to be "classic" fluence gradient-induced bow even when considering known "break-away" growth at higher fluence levels.
  - Apparent accelerated bow occurs at varying, higher exposures
  - Occurs primarily in high gradient (peripheral) locations
  - Guideline identifies additional susceptible control cells for surveillance

BWR Fuel Channel Bow Issue – 2008 Update
Operating Events (cont.)

> ## *Interim control rod friction surveillance guideline*

- *Cells identified for Grand Gulf Cycle 16*

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements

> ## *Recent poolside exams*

- ***October 2006 – Susquehanna Unit 2 MOC 13 shutdown, 26 80-mil FC (fuel channels), 2 100-mil FC, 32 GNF 80-mil FC***
  - ***Purpose of exam was to characterize channels suitable for continued irradiation***
  - ***Measurement data similar to past data on susceptible fuel channels***
    - ***Random occurrence of higher bow***
    - ***A biased sample of measurements***
- ***October 2007 – Susquehanna Unit 1 MOC15 shutdown, 74 Zry-2 100-mil, 2 Zry-2 80-mil and 2 Zry-4 80-mil FC***

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> *Recent poolside exams*

- ***March 2007 – Grand Gulf EOC 15, 34 114/67-mil AFC (Advanced Fuel Channels) and 5 114/67-mil AFC manufactured by Kobe Steel, Ltd.***
  - ***Obtain additional data on Zry-2 bow behavior***
  - ***Measure Kobe channels for qualification purposes***
  - ***Data used to confirm current surveillance guideline***
- ***February 2008 – LaSalle Unit 1 EOC12, 47 100-mil AREVA channels and 59 GNF channels***
  - ***Evaluate channel bow in problem cells to formulate corrective/preventive actions for next cycle.***
  - ***Improve surveillance for higher exposure Zry-2 fuel channels.***

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> *Recent poolside exams (continued)*

- *Grand Gulf EOC 15 – bow versus exposure*

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- Grand Gulf EOC 15 – bow versus fluence gradient

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- Grand Gulf EOC 15 – M-E versus exposure

[ ]

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- Grand Gulf EOC 15 – M-E versus EFID

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- May 2007 – Columbia Generation Station, 62 Zry-2 100-mil FC
  - Purpose of exam to confirm applicability of abnormal bow data from LaSalle units (also Zry-2 100-mil FC) to CGS.
  - FC selected with wide range of early-in-life control.

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- CGS EOC 18 – bow versus exposure

[ ]

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- CGS EOC 18 – bow versus fluence gradient

[

]

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> Recent poolside exams

- CGS EOC 18 – M-E versus exposure

BWR Fuel Channel Bow Issue – 2008 Update
Fuel Channel Measurements (cont.)

> **Recent poolside exams**

- **CGS EOC 18 – M-E versus EFID**

[ ]

BWR Fuel Channel Bow Issue – 2008 Update
Hot Cell Examinations

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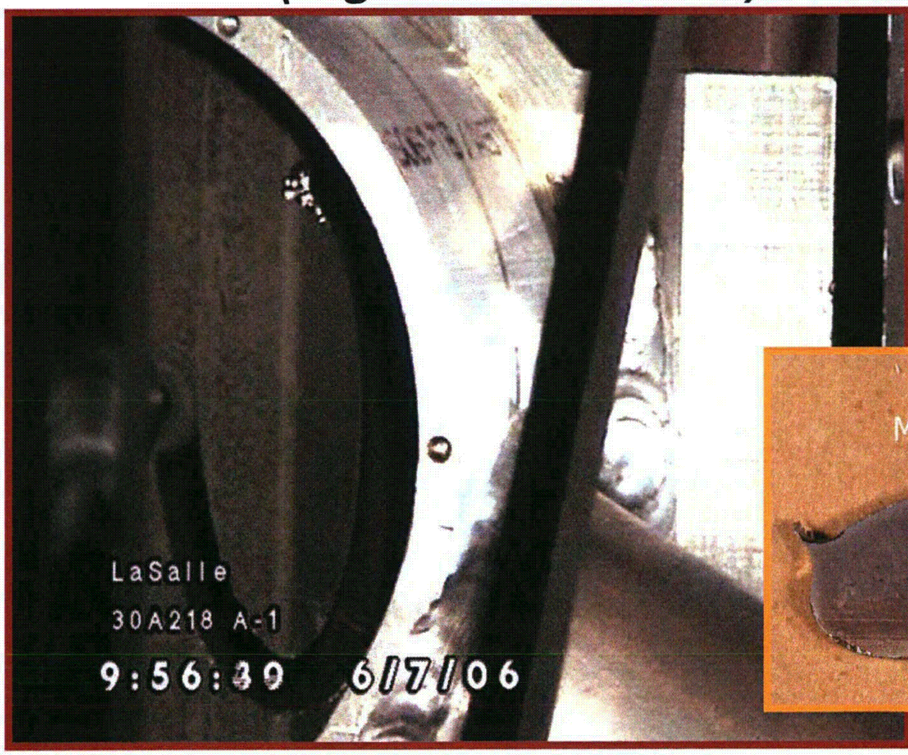
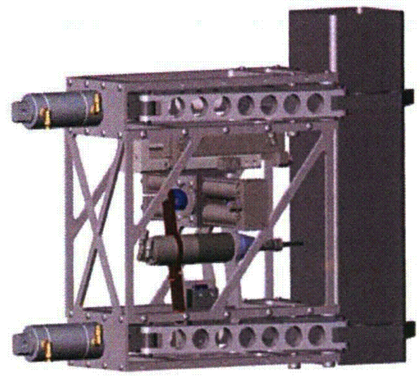
> Poolside examinations have clearly shown that only fuel channels fabricated from Zry-2 have exhibited unexpected channel bow.
> Zry-4 channels all have been shown to fall within limits of expected fuel behavior.
  - Standard modeling based on pressure and fluence history remains valid for Zry-4 fuel channels.
> Mechanism of unexpected channel bow and basis for difference in Zry-2 and Zry-4 fuel channel behavior could not be determined from poolside data.

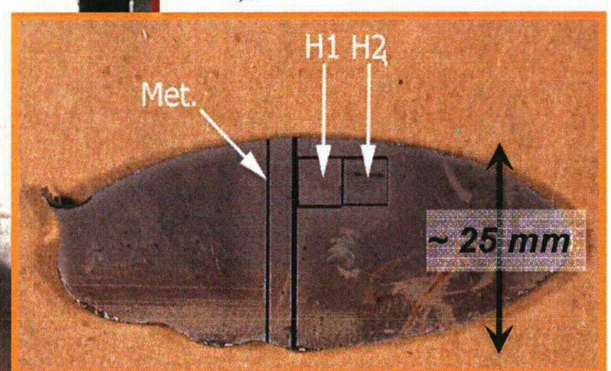
BWR Fuel Channel Bow Issue – 2008 Update
Hot Cell Examinations (cont.)

> Hot cell examinations:

- ***AREVA NP performed several hot cell examinations of Zircaloy-2 and Zircaloy-4 fuel channel coupons derived from two plants in the U.S. (together with EPRI)***







BWR Fuel Channel Bow Issue – 2008 Update
Hot Cell Examinations (cont.)

> Hot cell examinations have confirmed that Zry-4 does not exhibit the same sensitivity to shadow corrosion as Zry-2

BWR Fuel Channel Bow Issue – 2008 Update
Cell Friction

> ## Cell friction predictions

- *Currently, the AREVA fuel channel topical report, EMF-93-177(P)(A) Revision 1, describes the method for calculating control rod interference due to channel distortion*

  [ ]

  - *Closed-form solution for calculating channel bulge*
  - *Simple model for calculating control rod interference*

- *A new method is under development*

  [ ]

  - *Finite element method to calculate bulge*
  - *More elaborate 3-D cell friction calculation*

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BWR Fuel Channel Bow Issue – 2008 Update
Cell Friction (cont.)

> *Cell friction predictions*

- *Model development continues – need to take into account recent data on accelerated bow at higher exposures (OEs)*
- *Prediction of abnormal bow remains problematic*
- *To date, Zry-4 fuel channels exhibit predictable behavior*

> *AREVA will submit a revised topical report that uses fluence gradient to characterize bow rather than exposure*

- *Improved model can be used to identify control cells for surveillance*

BWR Fuel Channel Bow Issue – 2008 Update
Intermediate and Long-term Plans

> **Short term - Zry-4 material viewed as a short to medium-term solution**

- *While Zry-4 exhibits higher corrosion than Zry-2, Zry-4 wall thinning is acceptable up to the current exposure limit*

[ ]

BWR Fuel Channel Bow
Intermediate and Long-term Plans (cont.)

> Long term - AREVA has advanced materials and processes available for introduction:

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BWR Fuel Channel Bow Issue – 2008 Update Summary

> Summary

- ***Zry-2 fuel channels will continue to be a challenge to manage until full transition to Zry-4 fuel channels***
  - *Core design to take into consideration potential bow problems*
  - *Increased surveillance of control cells*
  - *Fuel channel replacement depending on perceived risk*
- ***There is a contribution of operating conditions to the channel bow issue but it is not well understood***
- ***Material development***
  - *Efforts to introduce LTAs are in progress*

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PWR Fuel and Hardware Testing Programs

Rose Montgomery

PIE Coordinator,

Fuel Mechanical & Structural Design

Fuel & Hardware Testing Programs

> PWR Programs
- **Objectives**
- *Test Assembly Programs*
- *2006-2007 Poolside PIEs*
- *M5 Experience Summary*
- *M5 Assembly growth models*
- *Unexpected Mark-B12 M5 guide tube growth*

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PWR Objectives

> Purpose of the latest PIE data is to specifically support:
  - Mark-B-HTP
  - Mark-B11A & B12 designs
  - Mark-BW & Advanced Mark-BW designs
  - CE designs
  - MONOBLOC guide tube design in U.S. reactors
  - Investigate M5 guide tube growth
  - Investigate fuel assembly distortion
  - Investigate fuel rod distortion

Fuel & Hardware Testing Programs

> **PWR Programs**

- *Objectives*
- ***Test Assembly Programs***
- *2006-2007 Poolside PIEs*
- *M5 Experience Summary*
- *M5 Assembly growth models*
- *Unexpected Mark-B12 M5 guide tube growth*

PWR Test Assembly Programs

> Mark-BW(A) (Sequoyah)

- *Objective*
  - *Provide performance data on design features*

- *4 test assemblies*
  - *Welded cage design with upper & lower HMP inconel grids*
  - *M5 fuel rods and MONOBLOC guide tubes*
  - *Insertion 10/07*
  - *Expectation is three cycles of operation to an end of life average assembly burnup of about 55 GWd/mtU*

- *Post Irradiation Examinations to be completed following each cycle*

PWR Test Assembly Programs (cont.)

> Advanced Mark-BW MOX (Catawba)

- Objective
  - Provide performance data on MOX

- 4 test assemblies
  - Standard Adv. BW design with M5 fuel rods, guide tubes, intermediate grids and MSMGs
  - Insertion 5/05
  - Expectation is three cycles of operation to an end of life average assembly burnup of about 52 GWd/mtU

- Post Irradiation Examinations to be completed following each cycle with hot cell rod exams following second and third cycles

PWR Test Assembly Programs (cont.)

> ## Zircaloy CE 14 assembly (Calvert Cliffs)

- **Objective**
  - Demonstrate design performance in Calvert Cliffs
  - High burnup demonstration
  - Provide performance data on design features

- **4 test assemblies**
  - M5 fuel rods and zircaloy guide tubes
  - Standard CE-type Welded cage design
  - Insertion in 2005
  - Expectation is three cycles of operation to an end of life peak pin burnup of about 68 GWd/mtU

- **Post Irradiation Examinations to be completed following each cycle**

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PWR Test Assembly Programs (cont.)

> M5 CE 14 XL assembly (Palo Verde)

- Objective
  - Demonstrate design performance in Palo Verde
  - Provide performance data on design features
- 4 test assemblies
  - M5 fuel rods and guide tubes
  - Standard CE-type Welded cage design
  - Insertion scheduled for 10/08
  - Expectation is three cycles of operation to an end of life average assembly burnup of about 55 GWd/mtU
- Post Irradiation Examinations to be completed following each cycle

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Fuel & Hardware Testing Programs

> **PWR Programs**
- *Objectives*
- *Test Assembly Programs*
- ***2006-2007 Poolside PIEs***
- *M5 Experience Summary*
- *M5 Assembly growth models*
- *Unexpected Mark-B12 M5 guide tube growth*

2006-2007 PWR Poolside PIEs

> 22 GWd/mtU Advanced Mark-BW MOX (Catawba)
- 4 lead assemblies
  - M5 fuel rods
  - M5 guide tubes
  - M5 intermediate & mid-span mixing grids
  - inconel upper & lower end grids
- Fuel assembly visual examination
- Assembly length, shoulder gap, rod growth
- Fuel assembly bow

2006-2007 PWR Poolside PIEs (cont.)

> 27 to 54 GWd/mtU Mark-BW (Sequoyah 2)
  - M5 fuel rods
  - M5 guide tubes
  - Zirc intermediate grids
  - inconel upper & lower end grids
- Fuel assembly visual examination
- Assembly length (48 assemblies)
- Shoulder gap & rod growth (9 assemblies)
- Fuel rod diameter & oxide thickness (4 assemblies)
- Fuel assembly bow (3 assemblies) & rod bow (3 assemblies)
- Rod lift to look for fretting marks in support of revised INPO guidelines (1 assembly selected in worst-case reactor location, 12 rods viewed)

> 21 to 26 GWd/mtU Mark-BW (Sequoyah 1)
  - Reduced holddown
- Assembly length (4 assemblies)
- Shoulder gap & rod growth (4 assemblies)
- Zirc Grid growth (4 assemblies)
- Fuel Assembly bow (4 assemblies)

2006-2007 PWR Poolside PIEs (cont.)

> 49 GWd/mtU Alliance (Sequoyah 2)
  - M5 fuel rods
  - M5 guide tubes
  - M5 intermediate grids
  - Welded cage
  - Bi-metallic upper & lower end grids
- Fuel assembly visual examination (3 assemblies)
- Assembly length (3 assemblies)
- shoulder gap & rod growth (1 assembly)
- Fuel rod diameter & oxide thickness (2 assemblies)
- Fuel rod bow (2 assemblies)

2006-2007 PWR Poolside PIEs (cont.)

> 20 to 48 GWd/mtU Advanced Mark-BW (N. Anna)

- M5 fuel rods
- M5 guide tubes
- M5 intermediate grids with inconel upper & lower end grids
- Assembly length (23 assemblies)

> 16 to 53 GWd/mtU Mark-B11A (Oconee 2 & 3)

- M5 fuel rods
- M5 guide tubes
- Zirc intermediate grids with inconel upper & lower end grids
- Assembly length (39 assemblies)

> 38 to 49 GWd/mtU Mark-B12 (Davis-Besse)

- M5 fuel rods
- M5 guide tubes
- zircaloy intermediate grids with upper & lower inconel grids
- Assembly length (15 assemblies)

2006-2007 PWR Poolside PIEs (cont.)

> 48 GWd/mtU Mark-B12 (TMI-1)
  - M5 fuel rods, M5 guide tubes, zirc intermediate grids with inconel upper & lower end grids
  - Assembly length (24 assemblies)
  - Assembly length confirmation (measuring tape)
  - Shoulder gap & rod growth
  - Guide tube ID oxide thickness
  - Extensive visuals
    - Standard 4-face visuals
    - Pulled rods to allow visuals of the guide tubes and instrumentation tube/grid restraint system
  - Holddown spring rate
  - Axial grid location
  - Fuel assembly distortion
  - Grid slip load
  - Control rod drag
  - Guide tube segment extraction for hot cell

> 23 to 54 GWd/mtU Mark-B12 (TMI-1)
  - Assembly length (35 assemblies)

2006-2007 PWR Poolside PIEs (cont.)

> 9 to 50 GWd/mtU Mark-B-HTP (Crystal River 3)

- M5 fuel rods
- M5 guide tubes
- M5 HTP grids with lower inconel HMP grid

- Assembly length (19 assemblies)
- Transverse grid growth

> 14 to 25 GWd/mtU Mark-B-HTP (Davis-Besse)

- M5 fuel rods
- M5 guide tubes
- M5 HTP grids with lower inconel HMP grid

- Assembly length (6 assemblies)
- Transverse grid growth

2006-2007 PWR Poolside PIEs (cont.)

> ~40 GWd/mtU CE14 (Calvert Cliffs)

- 4 lead assemblies
  - M5 fuel rods
  - Zirc guide tubes
  - All HTP (zirc) grids
- Assembly length
- Shoulder gap & rod growth
- Fuel rod diameter & oxide thickness
- Loose rod "shake" test
- All results as expected

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Fuel & Hardware Testing Programs

> ## PWR Programs

- Objectives
- Test Assembly Programs
- 2006-2007 Poolside PIEs
- **M5 Experience Summary**
- M5 Assembly growth models
- Unexpected Mark-B12 M5 guide tube growth

M5 Experience Summary

> PIE data from 19 plants, 36 rods evaluated in hot cell, BU 71 GWd/mtU
> Corrosion well behaved at high burnup
> Fuel Rod Growth
- M5 fuel rod growth supports existing M5 model
  - U.S. data is consistent with worldwide data but is on the low side of the range
  - Rod growth slows above 40 GWd/MTU

> Fuel Assembly Growth
- Fuel assembly growth of Mark-BW & Advanced Mark-BW are higher than expected but within bounds of the design criteria
- Mark-B12 batch 16 anomalous growth identified at TMI-1; Davis-Besse B12 growth rate consistent with non-batch 16 TMI-1 growth
- Mark-B11A M5 fuel assembly growth is similar to non-batch 16 TMI-1 B12 and is somewhat higher than expected
- Mark-B-HTP assembly growth measurements indicate low growth rates early in life with increasing rates later in life
- Dependent on structure

M5 Experience Summary (cont.)

- M5 exhibits low oxidation kinetics, whatever the fuel management
  - Up to high burn-up (71 GWd/tU)
  - Under high power (338 W.cm-1)
  - With or without lithium addition
  - With or without zinc addition
- Some specific aspects of M5 fuel rods, typically pale rings or spots, have been observed. They are associated with a slight or even negligible oxide thickness increase
- No massive spalling has ever been observed
- M5 exhibits low hydriding kinetics; under operation, the hydrogen content remains lower than the solubility limit up to high burnups

M5 Experience Summary (cont.)

> *Fuel Rod Oxide*

M5 Experience Summary (cont.)

> *Fuel Rod Growth*

M5 Experience Summary (cont.)

> *Mark-BW and Advanced Mark-BW Assembly growth*

M5 Experience Summary (cont.)

> *Mark-B11A and Mark-12 Assembly growth*

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M5 Experience Summary (cont.)

> Mark-B-HTP Assembly growth

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M5 Experience Summary (cont.)

> Worldwide M5 Assembly growth

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Fuel & Hardware Testing Programs

> **PWR Programs**
- *Objectives*
- *Test Assembly Programs*
- *2006-2007 Poolside PIEs*
- *M5 Experience Summary*
- ***M5 Assembly growth models***
- *Unexpected Mark-B12 M5 guide tube growth*

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Assembly Growth Models

> Mark-BW, Adv. Mark-BW, MOX

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Assembly Growth Models (cont.)

> Mark-BW, Adv. Mark-BW, MOX

[ ]

Assembly Growth Models (cont.)

> Non-HTP Mark-B

Assembly Growth Models (cont.)

> Non-HTP Mark-B

[ ]

Assembly Growth Models (cont.)

> *Mark-B-HTP*

[ ]

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Assembly Growth Models (cont.)

> *Comparison: non-HTP Mark-B and Mark-BW with BAW-10227*

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Fuel & Hardware Testing Programs

> ## PWR Programs

- Objectives
- Test Assembly Programs
- 2006-2007 Poolside PIEs
- M5 Experience Summary
- M5 Assembly growth models
- **Unexpected Mark-B12 M5 guide tube growth**

Unexpected Mark-B12 M5 Guide Tube Growth

- History
- Extent of condition
- Status & Follow up measurements
- Next Steps
- Conclusions

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Unexpected Mark-B12 M5 Guide Tube Growth History: 01

> Measured 24 fuel assemblies in May '07
  - Inspections planned for baffle interaction PIE
  - Growth measurements added to increase database
> All assemblies measured were of same batch
  - M5 fuel rods and guide tubes, Zr-4 intermediate grids
> All assemblies at about 48 GWd/mtU
> All assemblies exhibited a growth rate much higher than expected – even higher than expected for zircaloy
> Increasing shoulder gap observed
  - Considered an anomaly for any structure with the same fuel rod cladding and guide tube material

Unexpected Mark-B12 M5 Guide Tube Growth History: 02

Unexpected Mark-B12 M5 Guide Tube Growth History: 03

> Issue resulted in hard contact with reactor internals

> Actions taken

- Fuel and reactor internals evaluations complete that assure continued safe operation
- Measurements taken to confirm growth is within design limits for other fuel designs and reactors
- Upper end fittings replaced on Mark-B12 fuel (TMI and D-B)
- Extensive review of material characteristics

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Unexpected Mark-B12 M5 Guide Tube Growth Extent of Condition: 01

- TMI was the lead plant for Mark-B12 and is finishing their 3rd Cycle with the FA's
- Davis Besse will complete their 2nd Cycle with Mark-B12 FA's on December 30th
- Oconee-2 will complete their 3rd Cycle with Mark-B11A (similar to B12) FA's on October 20th
- Crystal River-3 will complete their 2nd Cycle with Mark-B HTP FA's on November 3rd

Unexpected Mark-B12 M5 Guide Tube Growth Status: 01

> *Current emphasis is on root cause analysis, material characterization and development of predictive growth tool*

> *Recommend continued fuel growth measurements to confirm absence*

Focusing on finding causes and implementing solution

Unexpected Mark-B12 M5 Guide Tube Growth Status: 02

> *Material/Chemistry Investigations Completed*
  - *Material composition of ingot*
  - *Microstructure of archive GT material*
  - *Texture of archive GT material*
  - *Guide tube oxide at TMI*
  - *Creep tests (uniaxial and biaxial) of archive GT material*
  - *Plant chemistry investigation*
  - *Measurements of FAs using same M5 ingot material at other reactors (OCO fuel rods – SQN & D-B not completed)*
  - *No single material related contributor identified to date*

> *Assembly Design Investigations*
  - *Effects of increased slip load on FA growth*
    - *Using predictive tool to generate "relative" design behavior*
  - *Comparison with almost identical B11A design at OCO show that B12 growth at TMI is not expected based on GT stress conditions alone; increased slip load alone could not have caused condition*

Unexpected Mark-B12 M5 Guide Tube Growth Status: 03

> ***Assembly Manufacture Investigations***
- *Review of as-built data (lengths, grid cells, certs, specs)*
- *Review of guide tube manufacturing process (Cezus)*
- *Archive component testing*
  - *Holddown spring tests in hot conditions completed*
  - *Grid slip load tests with Zr-4 and M5 fuel rods completed*

> ***International task force of global AREVA experts created, applying additional resources to***
- *Explain the cause of high growth at TMI*
- *Validate design sensitivities and key design attributes*

Unexpected Mark-B12 M5 Guide Tube Growth

Follow-up Inspections Completed to date

> 16 to 53 GWd/mtU Mark-B11A (Oconee 2 & 3)
> 39 assemblies

> 23 to 54 GWd/mtU Mark-B12 (TMI-1)
> 35 assemblies

> 9 to 50 GWd/mtU Mark-B12 (Davis-Besse)
> 15 assemblies

> 9 to 50 GWd/mtU Mark-B-HTP (Crystal River 3)
> 19 assemblies

> 9 to 50 GWd/mtU Mark-B-HTP (Davis-Besse)
> 6 assemblies

Unexpected Mark-B12 M5 Guide Tube Growth Next Steps

> Complete TMI and North Anna LTA GT segment Hot Cell Exams - 4/08
> Complete creep tests on additional archive samples (Mark-B11 and Mark-B-HTP) – 3/08
> Evaluate results and issue findings – 4/08
> Continue to monitor fuel behavior
  - Catawba 1 – Advanced Mark-BW (MOX) – 6/08
  - North Anna 2 – Advanced Mark-BW – 9/08
> Incorporate results in design tools ongoing

Plan in place to identify causes

Unexpected Mark-B12 M5 Guide Tube Growth Conclusions

> *Fuel assembly growth was higher than anticipated and to-date is not fully explained*

> *A comprehensive guide tube material examination program has not yet found an M5 material effect*

> *RCA and technical investigations continuing to improve understanding and identifying solution*

> *Monitoring operating experience and collecting PIE will validate solution*

AREVA on track to resolving issue

Conclusion

Ronnie L. Gardner
Manager, Site Operations &
Corporate Regulatory Affairs