AREVA NP Inc.
Fuel Performance Meeting

June 9 and 10, 2011
Rockville, Md.

AREVA NP Inc.

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2011 Fuel Performance Meeting

Pedro Salas
Manager, Corporate Regulatory Affairs

Rockville, Md.
June 9 and 10, 2011

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Agenda – June 9, 2011

- *9:00 Welcome and Introductions – Wilkerson/Salas*
- *9:15 Description of AREVA NP Inc. – Salas*
- *9:45 Program Issues – Kliewer*
- *12:00 Lunch*
- *1:00 PWR Fuel Designs - Williams*
- *2:00 PWR Core Engineering Methods - DeLorey*
- *3:00 BWR Fuel Designs - Garner*
- *4:00 BWR Core Engineering Methods - Pruitt*
- *5:00 Adjourn*

Agenda – June 10, 2011

- *9:00 BWR Operating Experience/Fuel Exams - Garner*
- *10:30 PWR Operating Experience/Fuel Exams - Mohan*
- *12:00 Lunch*
- *1:00 Cruciform Spring Update - Gardner*
- *2:00 Crud Risk Management Tools - Harne*
- *3:00 Closing Remarks*
- *3:30 Adjourn*

Objectives

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Objectives

- ***Outline of discussion***
  - *Program issues*
  - *Fuel designs*
  - *Core engineering methods*
  - *Operating experience*
  - *Fuel exams*
  - *Observations and solutions*

- ***Objectives***
  - *Understanding AREVA's fuel designs and methods*
  - *Exchanging ideas and expectations on fuel issues*
  - *Open communication; ask questions*

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Description of AREVA NP Inc.

Pedro Salas
Manager, Corporate Regulatory Affairs

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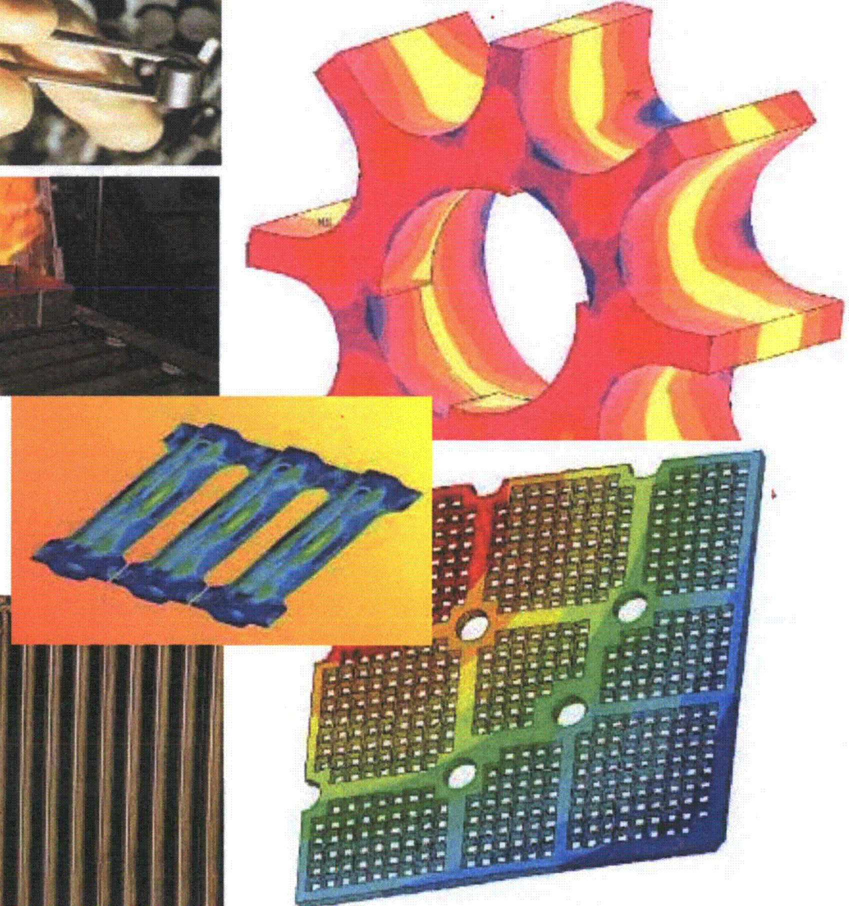
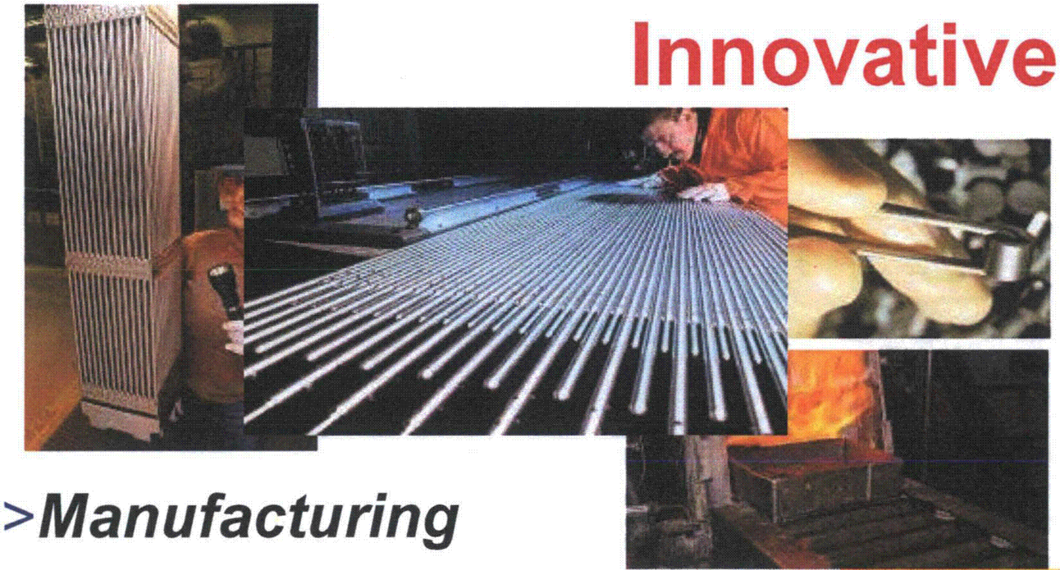
Global Integration & Innovative Solutions

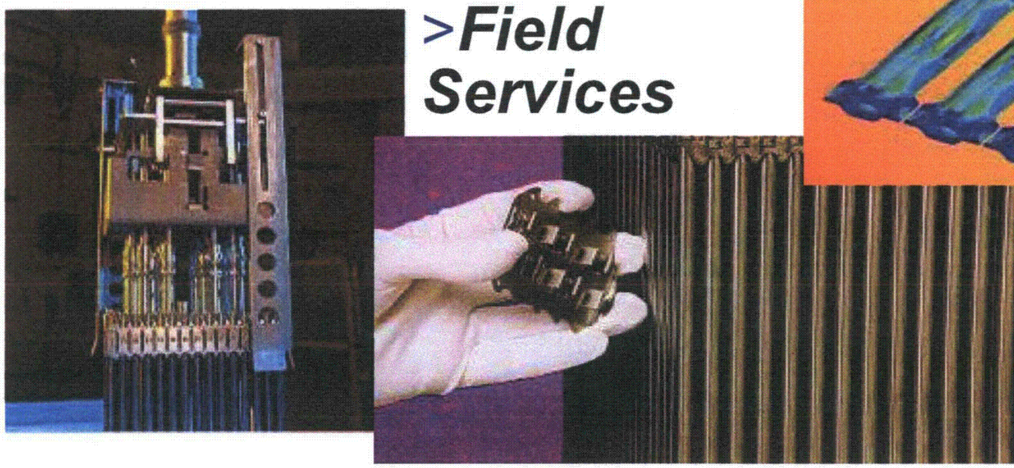
>Engineering





>Manufacturing

>Field Services



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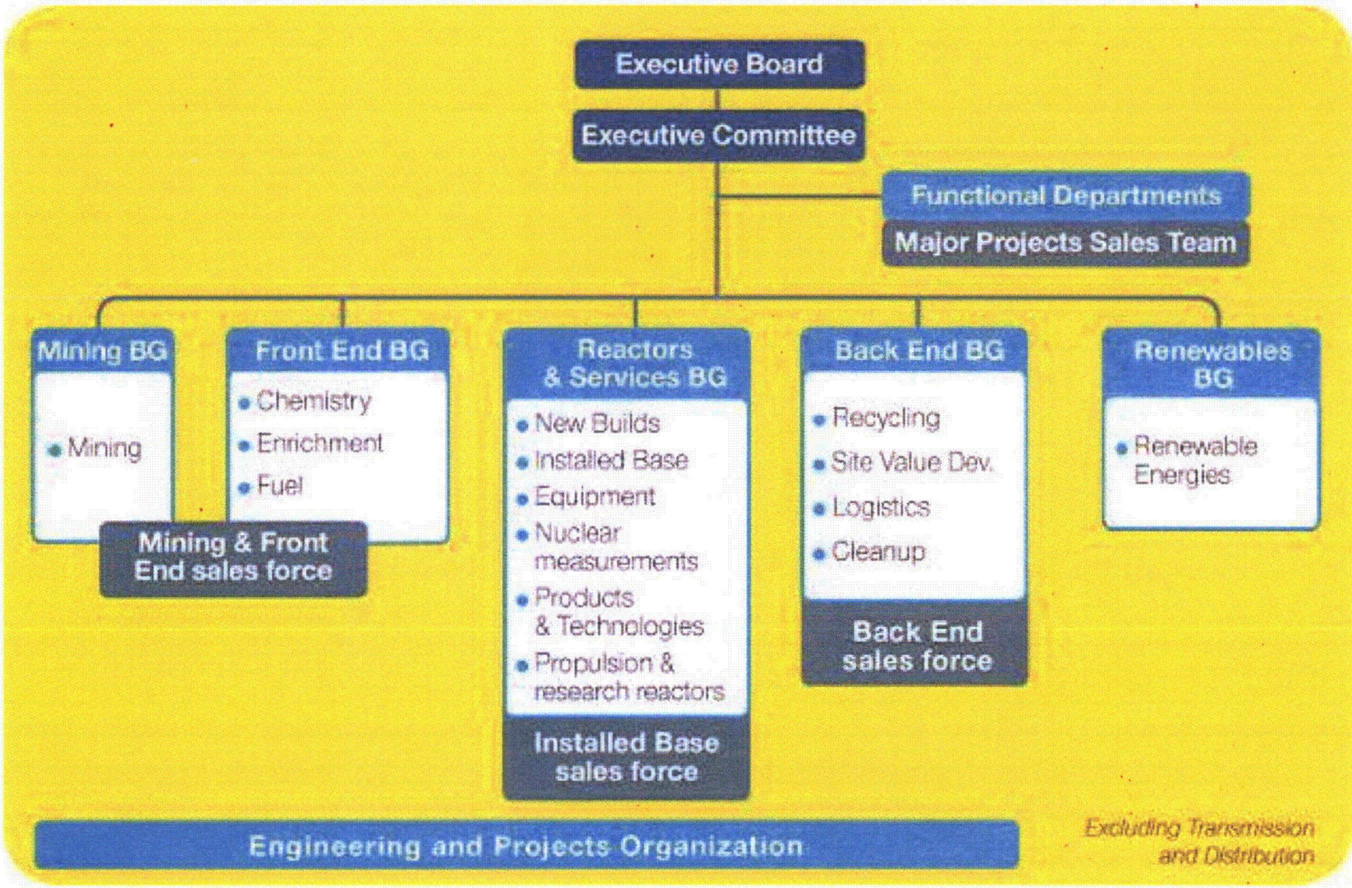
Creation of Business Group



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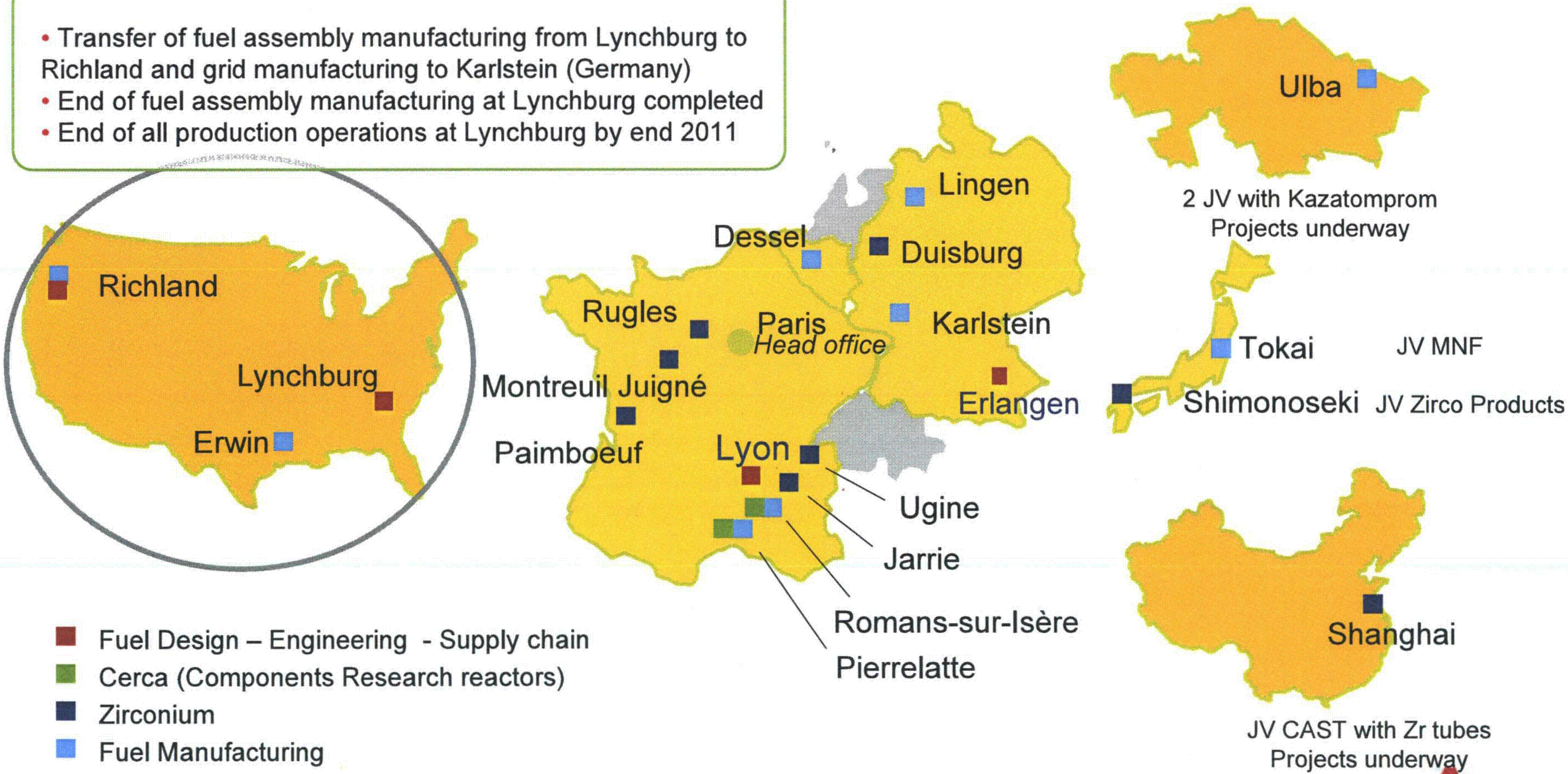
AREVA Fuel Worldwide Serves Our Utility Customers

▶ Optimization of US Industrial Footprint

- Transfer of fuel assembly manufacturing from Lynchburg to Richland and grid manufacturing to Karlstein (Germany)
- End of fuel assembly manufacturing at Lynchburg completed
- End of all production operations at Lynchburg by end 2011



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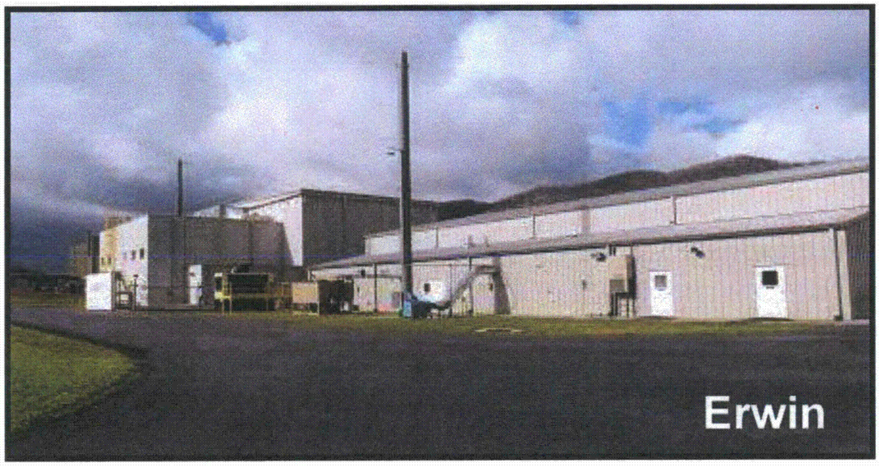
Nuclear Fuel



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AREVA US Fuel Customers

Data Source: FSDD 3/3/11

NA-2 Last Delivery 8/2011
Monticello – 2011 New Contract
Songs 3 – 2011 or 2012

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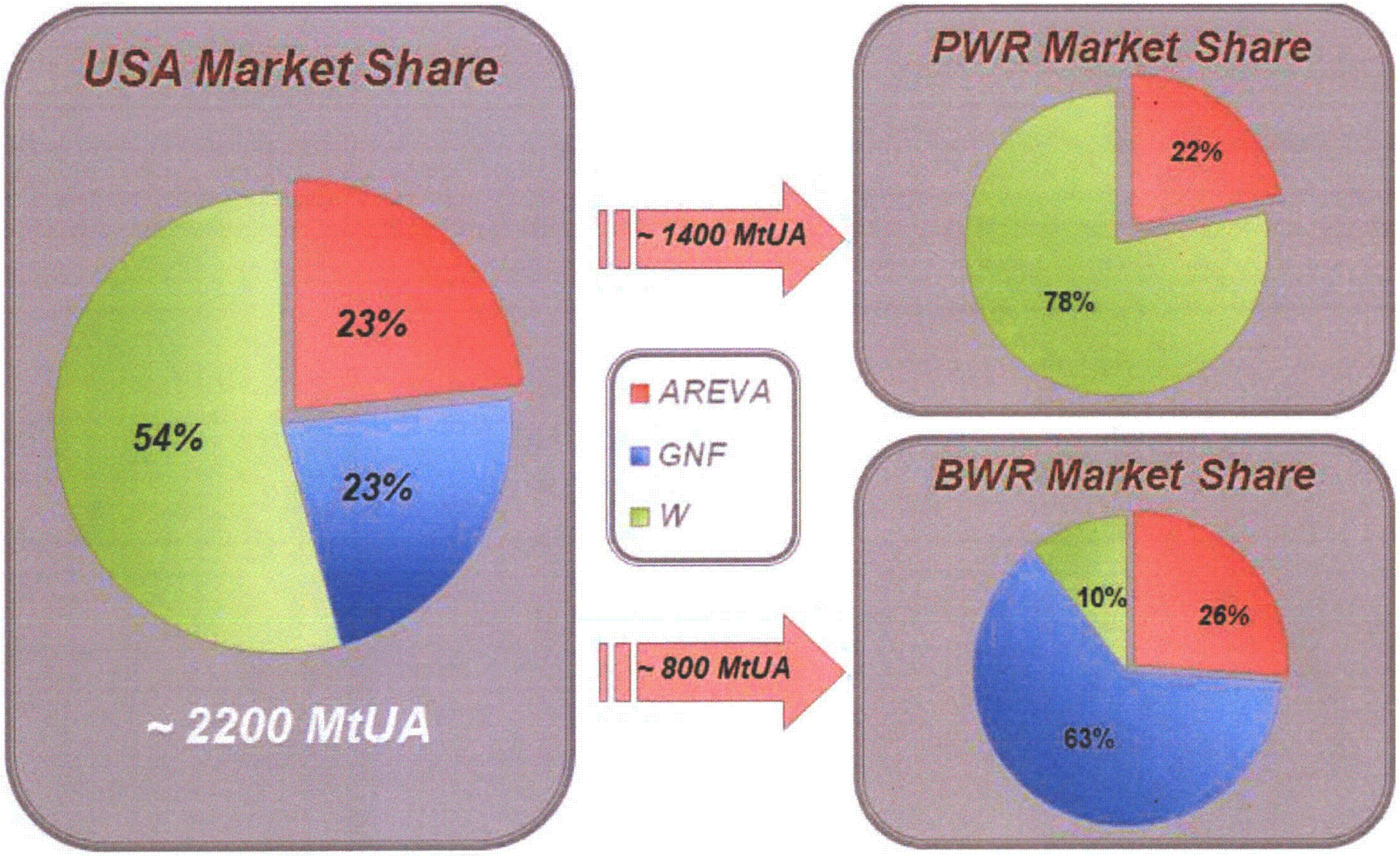
US Fuel Market Share
For External Publication: Updated May 2011



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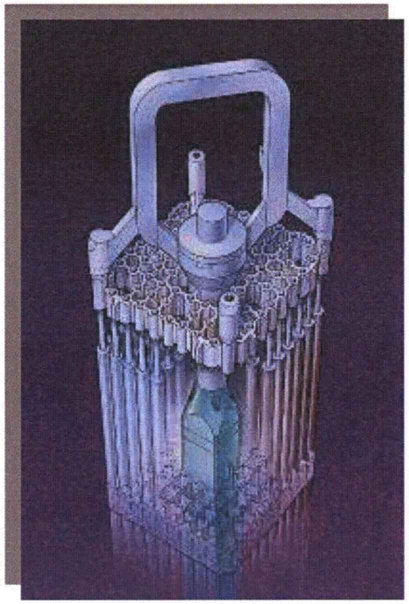
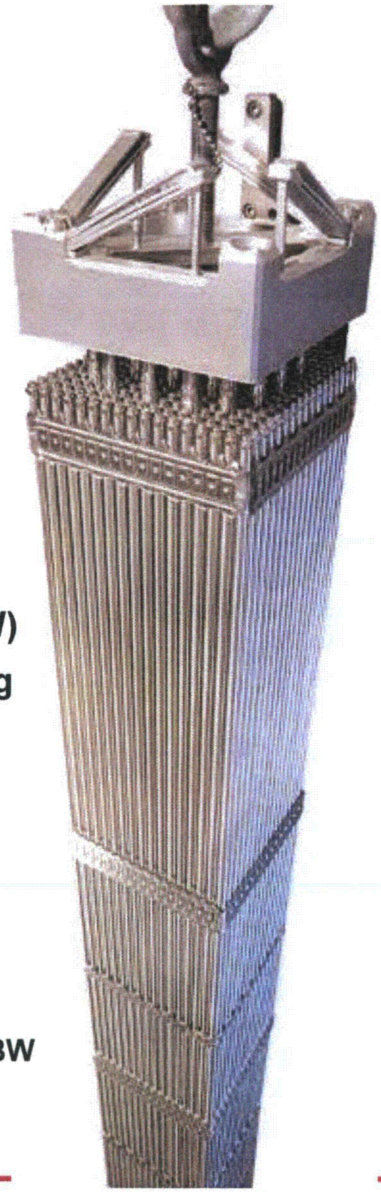
Fuel Products



ATRIUM™ 10XM

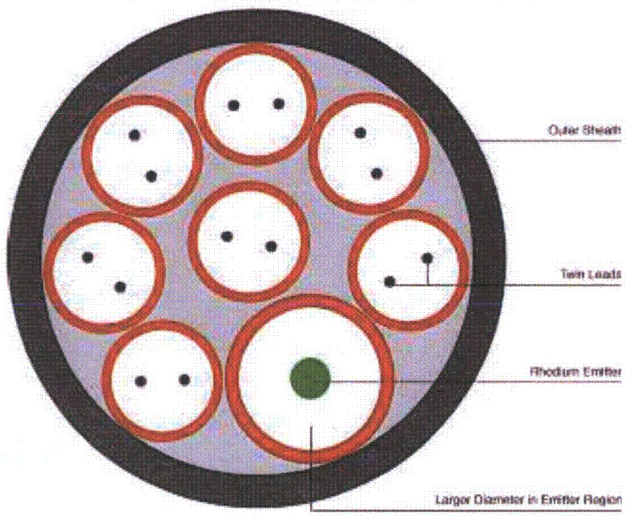
- **Boiling water reactor (BWR) fuel – Plant Designs**
  - GE
  - Siemens
  - ASEA
- **Pressurized water reactor (PWR) fuel – Plant Designs**
  - Babcock & Wilcox (B&W)
  - Combustion Engineering (C-E)
  - Westinghouse (W)
  - Siemens
  - AREVA NP



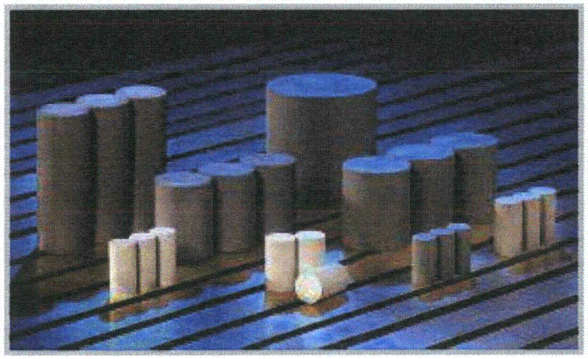
Advanced Mark-BW

Fuel-Related Components

- Control components for B&W, C-E and W plants
- Burnable poison rod assemblies for B&W, C-E and W plants
- Incore detectors for B&W, C-E and W plants
- Flux thimble thermocouple tubes for W plants



Incore Detector



Burnable Poison Pellets

BPRAs

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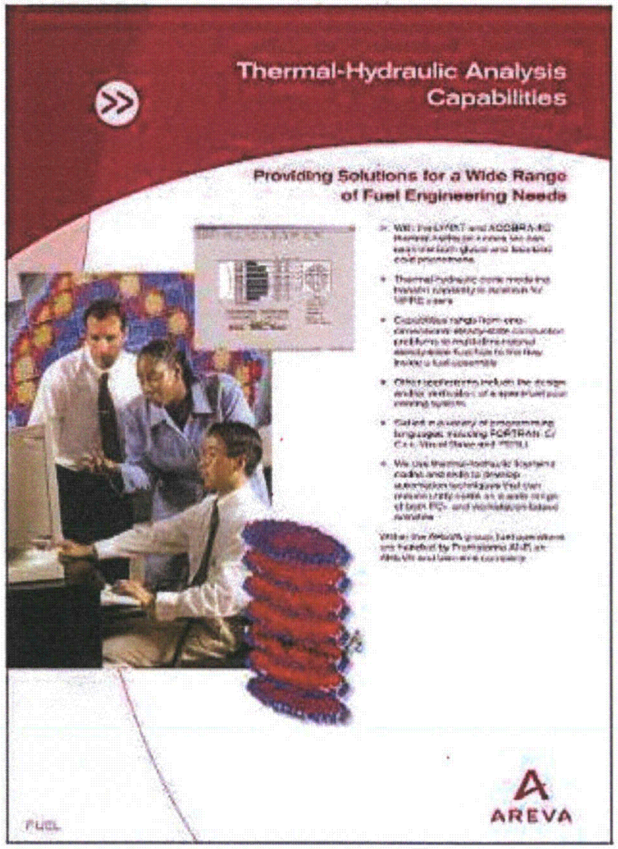
Services Engineering

- Core design and licensing
- Licensed power increases
- Reactor engineering analysis and on-site support
- Criticality analysis for spent fuel
- Structural analysis for fuel and related products
- Technology transfer for reload licensing and related codes and methods
- Advanced realistic large-break LOCA methodology
- Chemistry & Crud Risk Assessment Tools
- Special studies



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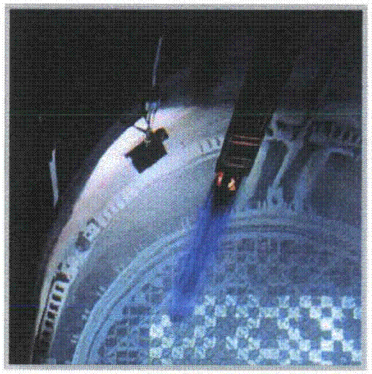
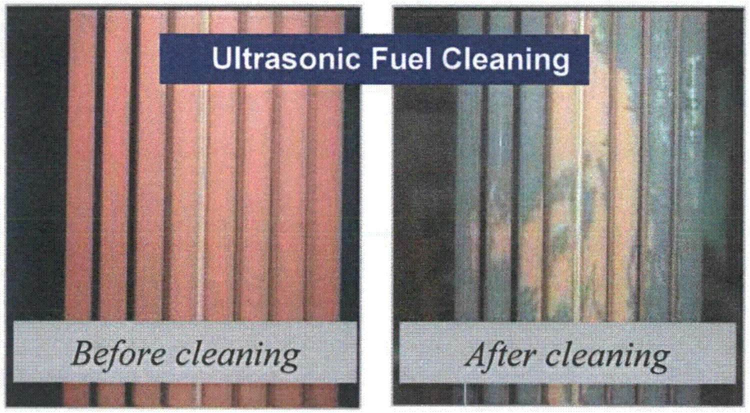
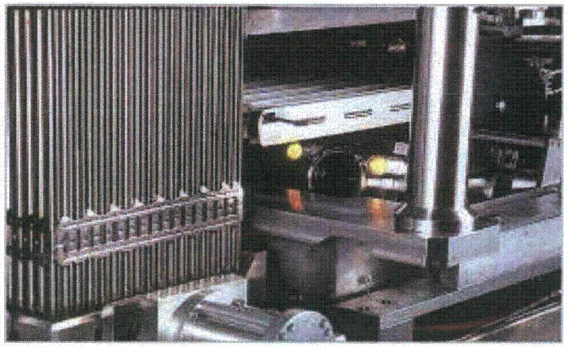
Fuel Services

- Fuel Inspections
  - Ultrasound
  - Eddy Current
  - Fuel Sipping
- Fuel Cleaning
- Fuel Repair & Reconstitution
- Specialty Tooling







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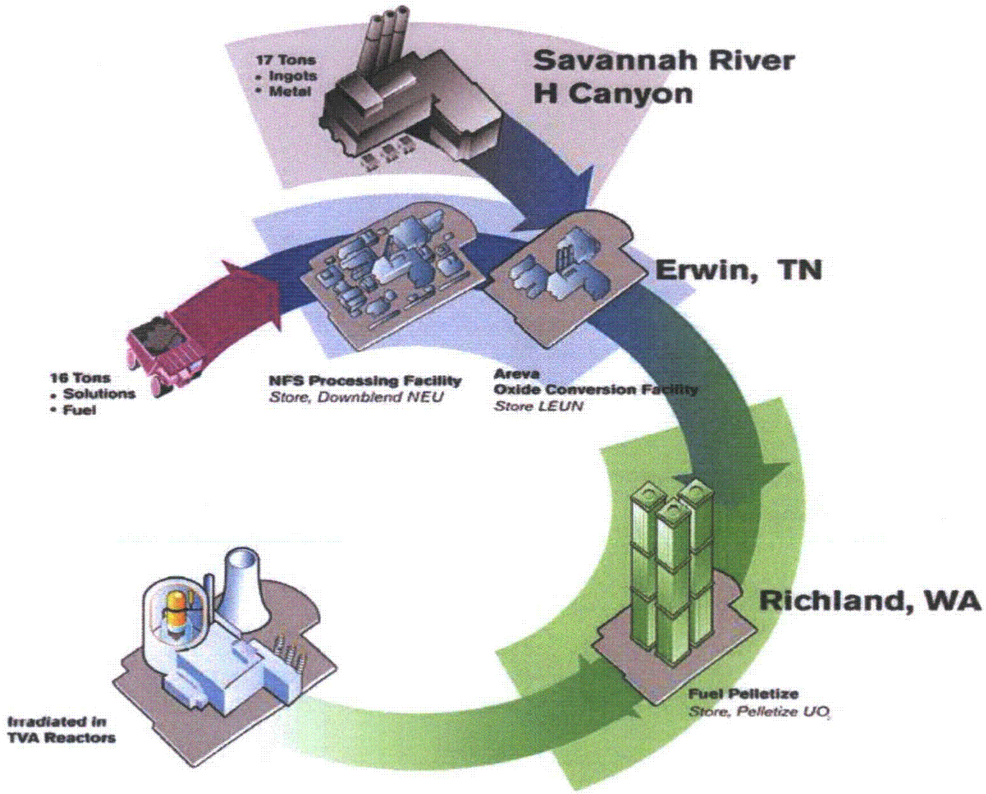
Proprietary

Operations
Horn Rapids Road Facility

- Constructed in 1971
- Facility size: 404,000 square feet
- Shipped over 49,000 fuel assemblies since 1971
- Over 270 powder shipments since 1990
- Over 420 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
- Certification: ISO 9001

Operations
BLEU Conversion Complex



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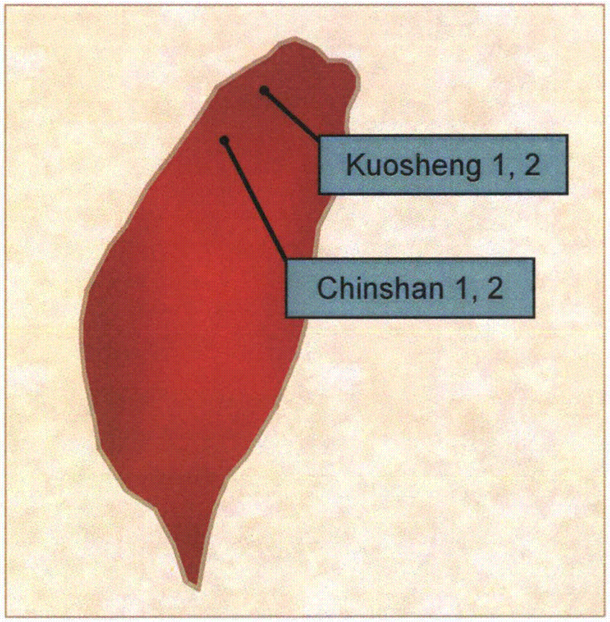
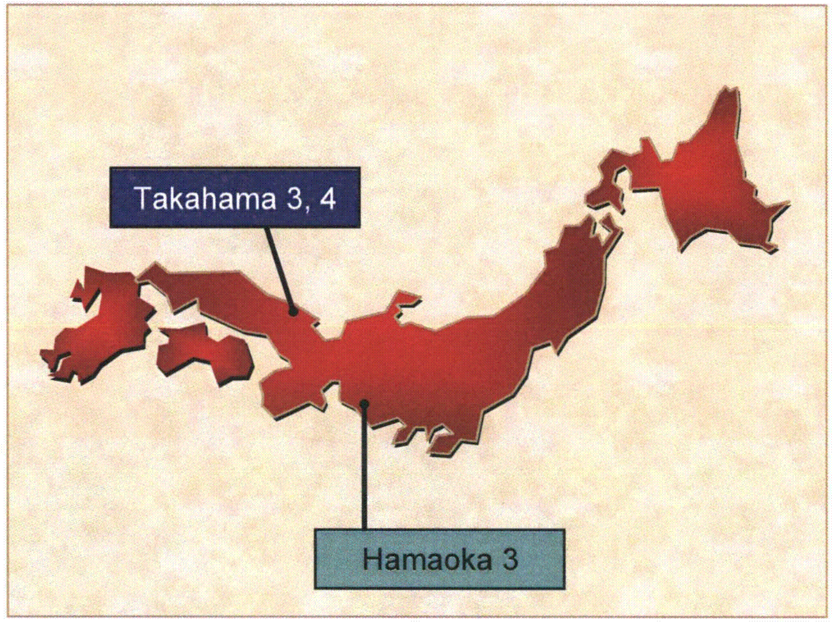
Fuel Customers in Taiwan and Japan





Taiwan

Japan

BWR

PWR

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PWR Method Issues

Rod Kliewer
Contract Manager, Front End

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Agenda

- Introduction
- Technical Details
  - Realistic Large Break LOCA
  - Small Break LOCA
  - Non-LOCA Safety Analysis
  - Fuel Performance
- Moving Forward
- Summary and Conclusions

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Introduction

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Objective

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AREVA takes the issue seriously and is committed to action

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The AREVA Fuel Excellence Plan
Our roadmap to deliver expectations

Clear Gap Exists

Impacts

Upcoming PWR LARs

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Overview of Recovery W/CE Methodology

Technical Details

Note: Solutions discussed below will be presented in Topical Supplements

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Realistic Large Break LOCA Overview

Realistic Large Break LOCA Overview

Realistic Large Break LOCA Solutions Known

Realistic Large Break LOCA Solutions Known

Realistic Large Break LOCA Solutions to be Finalized

Realistic Large Break LOCA Solutions to be Finalized

Realistic Large Break LOCA Solutions to be Finalized

Realistic Large Break LOCA Summary

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Realistic Large Break LOCA Summary

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Small Break LOCA Overview

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Small Break LOCA Solutions Known

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Small Break LOCA Solutions Known

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Small Break LOCA Solutions Known

Small Break LOCA Solutions Known

Small Break LOCA Solutions to be Finalized

Small Break LOCA Solutions to be Finalized

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Small Break LOCA Summary

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Small Break LOCA Summary

Non-LOCA Safety Analysis Overview

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Non-LOCA Safety Analysis Solutions Known

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Non-LOCA Safety Analysis Solutions Known

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Non-LOCA Safety Analysis Solutions Known

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Non-LOCA Safety Analysis Solutions Known

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Non-LOCA Safety Analysis

Non-LOCA Safety Analysis Summary

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Thermal-Mechanical Analyses
Overview

Thermal-Mechanical Analyses
Overview

Thermal-Mechanical Analyses Solution Known

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Thermal-Mechanical Analyses Summary

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Moving Forward

Immediate Future

Interim Period

Development of Supplements

Supplemented Methods (W/CE)

Long-Term Solution

Timeline for Activities

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Wrap Up

Did we answer your questions?

Have we addressed your concerns?

PWR Fuel Design Update

Patrick Williams
Advisory Engineer – PWR Fuel

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Presentation Outline

- ▶*U.S. PWR Fuel Supply*
- ▶*Current PWR Fuel Designs and Planned Design Transitions*
- ▶*PWR Lead Assembly Programs*

Fuel Supply – Operating Plants by OEM

Babcock & Wilcox	Westinghouse	Combustion Engineering
Oconee 1,2,3 Arkansas Nuclear One 1 Three Mile Island 1 Davis Besse Crystal River 3	Sequoyah 1,2 (Reload and Leads) Harris Robinson Braidwood (Leads)	Millstone 2 St. Lucie 1 Ft. Calhoun Calvert Cliffs 1,2 Palisades Palo Verde 1 (Leads) San Onofre 2 (Leads)

Batch supply to 17 plants and lead fuel assemblies in 4 plants

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Fuel Designs – Operating Plants by OEM

Babcock & Wilcox	Westinghouse	Combustion Engineering
All seven units – Mark-B-HTP (15x15)	Sequoyah 1,2: Mark-BW 17x17 (+ Adv. Mark-BW(A) leads) Harris: 17x17 HTP Robinson: 15x15 HTP Braidwood 17 x 17 Advanced Mark-BW(A) (leads)	Millstone 2: 14x14 HTP St. Lucie 1: 14x14 HTP Ft. Calhoun: 14x14 HTP Palisades: 15x15 HTP Calvert Cliffs 1,2: 14x14 HTP Palo Verde 1: 16x16 HTP (leads) San Onofre 2: 16x16 HTP (leads)

AREVA currently has 13 PWR fuel assembly designs and is consolidating to the HTP Fuel Assembly Design Platform

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HTP Fuel Assembly Design Platform Key Fuel Assembly Components

- The HTP Fuel Assembly Design Platform consists of the following key attributes, which are implemented as applicable:
  - Chamfered Pellet
  - M5 Cladding
  - HTP Spacer Grid
  - Intermediate Flow Mixers (IFMs)
  - HMP Bottom Grid
  - MONOBLOC Guide Tube (only where dashpot required)
  - Welded Structure
  - Robust FUELGUARD Lower End Fitting
  - Quick Disconnect between Upper End Fitting and Guide Tubes (except Mark-B-HTP)

Implementation Process for the HTP Fuel Assembly Design Platform

- AREVA continues to implement HTP Fuel Assembly Design Platform components within its fuel assembly portfolio to address Operational Experience (OE) issues, improve performance margins and support anticipated operational upgrades

- Key attributes are implemented individually or as an entire platform as applicable
  - Operational Requirements
  - Customer Need

- Operational experience and applicability of similar applications support direct reload application

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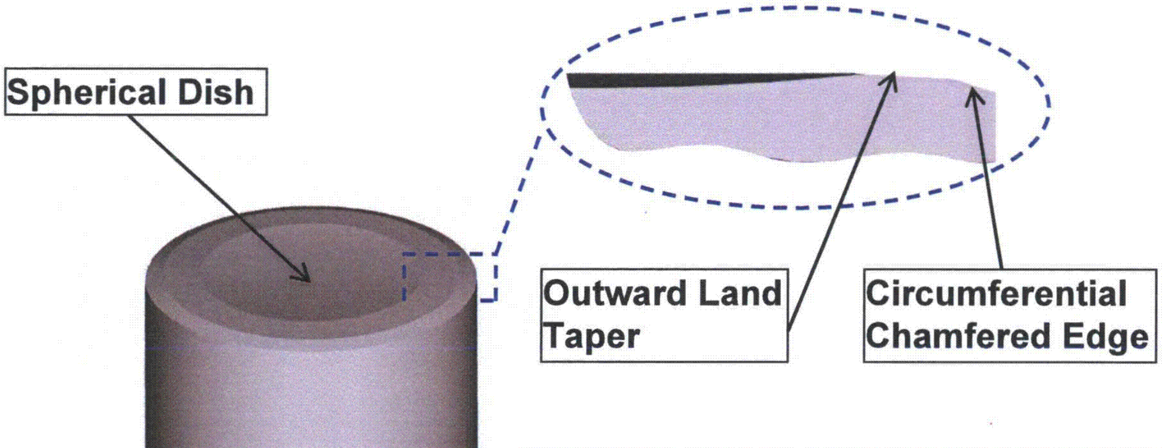
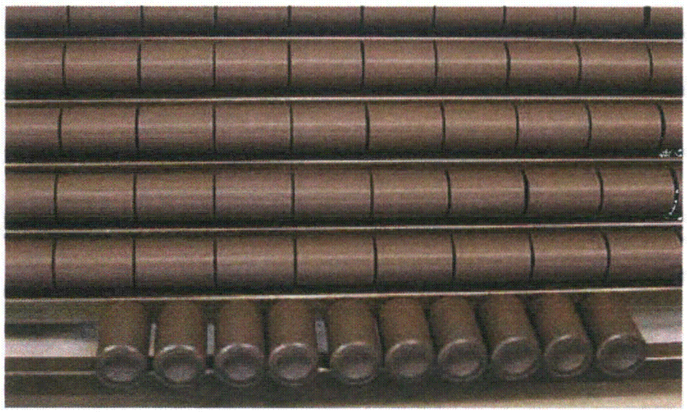
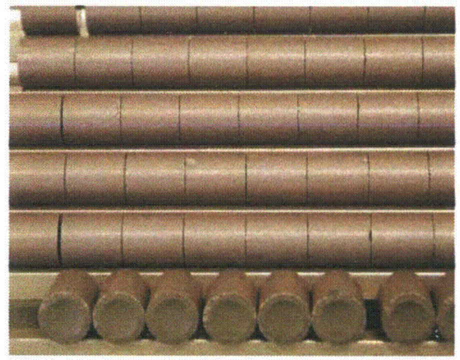
Key Fuel Assembly Components – Chamfered Pellet





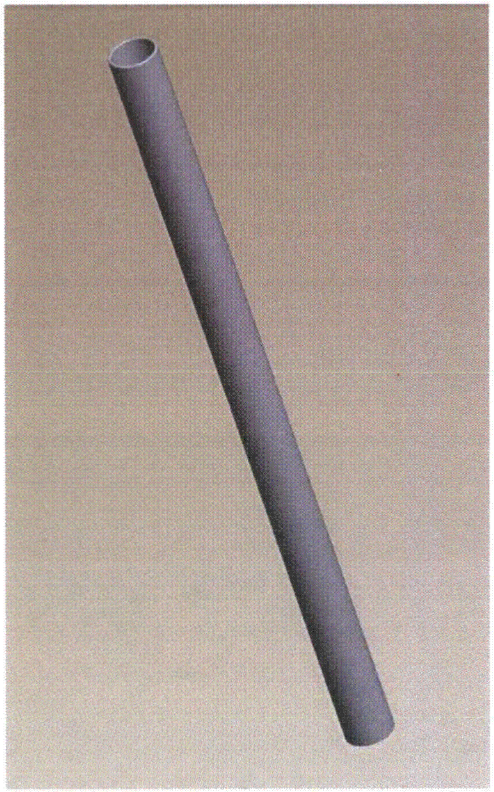
17x17 Pellet with chamfer



17x17 Pellet without chamfer

» Improved margin for Pellet – Cladding Interaction (PCI) through significant decrease in flaw generation

Key Fuel Assembly Components – M5 Cladding



- Low-oxidizing alloy
- Low Hydrogen pickup factor
- Higher burnup reliability
- Margin to proposed 10CFR50.46 LOCA Criteria - cladding maintains ductility post-LOCA

» **Ensures operational limits are not impacted due to burnup-dependent oxidation limits**

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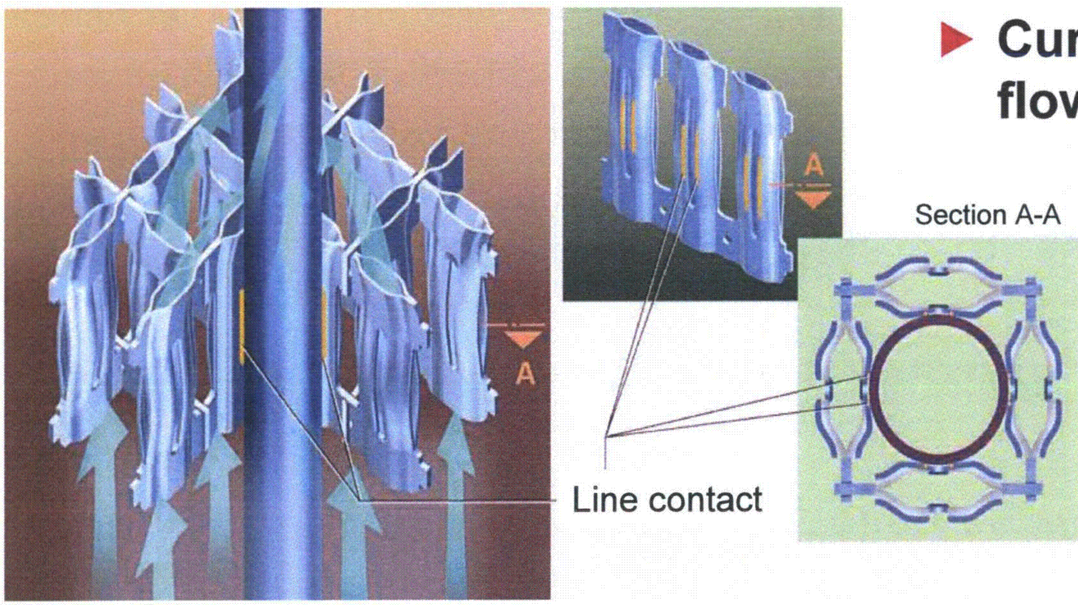
Key Fuel Assembly Components – HTP Spacer Grid

- Rod support and flow mixing in a single component
  - Balanced stiffness and damping characteristics
    - "Dual Line Contact" rod support system



- Curved flow channels for flow mixing
- Large contact area

» Contact geometry provides optimum resistance to grid to rod fretting (GTRF) with effective flow mixing

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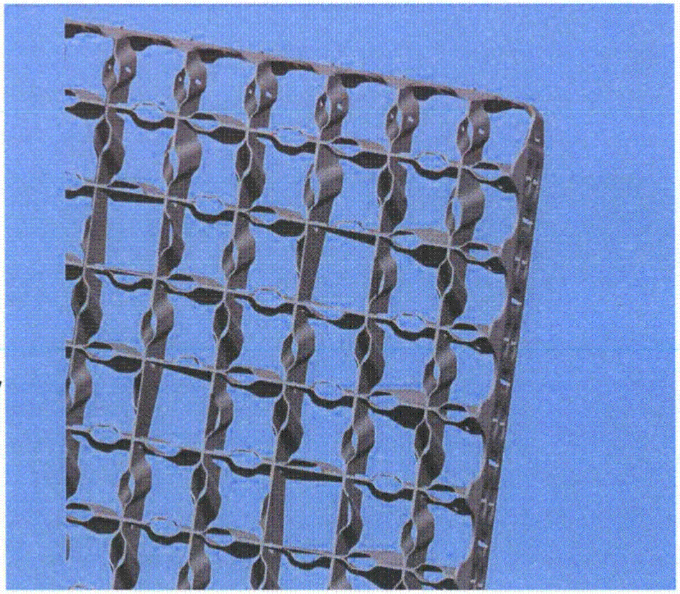
Key Fuel Assembly Components – IFM Grid

- Same rod support principle applied as with the HTP Spacer Grid
- "Angled" flow channels for flow mixing
- Efficiently designed to balance:
  - Optimize flow mixing
  - Minimize pressure losses
  - Maximize structural integrity
- Installed mid-span between HTP Spacer Grids to improve fuel assembly thermal-hydraulic performance



» Ensures optimal fuel efficiency and minimal cycle costs, with added benefit of structural robustness

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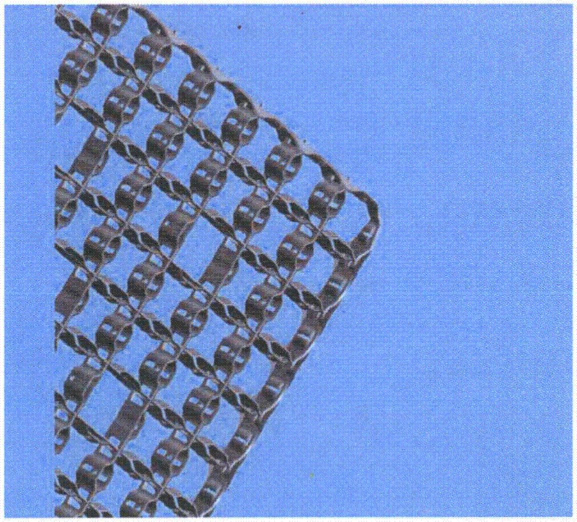
Key Fuel Assembly Components – HMP Bottom Grid

- Constructed using the same design concept as the HTP Spacer Grid
- Alloy 718 material for optimal strength and relaxation characteristics



- Straight (non-mixing) flow channels for:
  - Optimal fuel rod support
  - Flow conditioning and low pressure drop
  - Increased margin against flow induced vibration

Increased fuel assembly grid to rod fretting robustness

» **No known fretting failures in fuel assembly designs when applied with HTP Spacers and HMP Bottom Grids**

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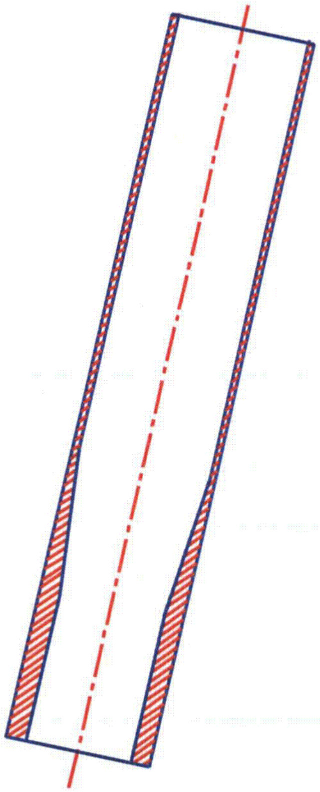
Key Fuel Assembly Components – MONOBLOC Guide Tube



- Single outer diameter with thicker wall at the dashpot region(s)
- Replacement for constant wall thickness "Swaged" Guide Tubes
- Measurable effect seen in improved control rod drop times
- Superior manufacturing process with regard to product quality
- In use since 1998, with over 27,600 Fuel assembly applications

» **Provides increased fuel assembly lateral stiffness for increased resistance against fuel assembly distortion**

Key Fuel Assembly Components – Welded Structure

- Spacer grids and flow mixing grids are welded directly to the guide tubes
- Alloy 718 end grids are captured tightly using Capture Rings welded to the guide tubes
  - Capture Rings above and below each HMP grid on each guide tube
  - Up to 8 welds total on Capture Rings (top and bottom)
- Optimum configuration is the combination of HTP Spacer Grids, IFM Grids, and HMP Bottom Grid
  - Up to 4 weld points per guide tube per HTP Spacer Grid and IFM Grid

» **Direct coupling between grids and guide tubes yield increased fuel assembly stiffness, which improves its resistance to fuel assembly distortion**

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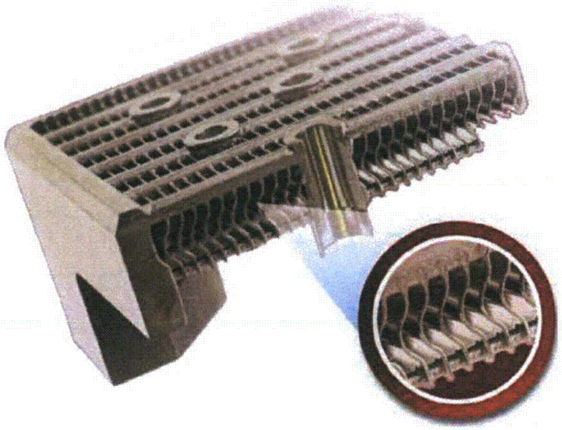
Key Fuel Assembly Components – Robust FUELGUARD Lower End Fitting

- Provides a "No-Line-of-Sight" flow path, which is very effective at trapping debris
- Structurally robust to resist impact damage by "Large" pieces of debris



- No debris-related failures known to have occurred at internal fuel assembly locations with application of the FUELGUARD filter
- Flow conditioning is improved for fuel assembly grid to rod fretting robustness

» **The Robust FUELGUARD Lower End Fitting is a proven solution in eliminating debris related fuel failures**

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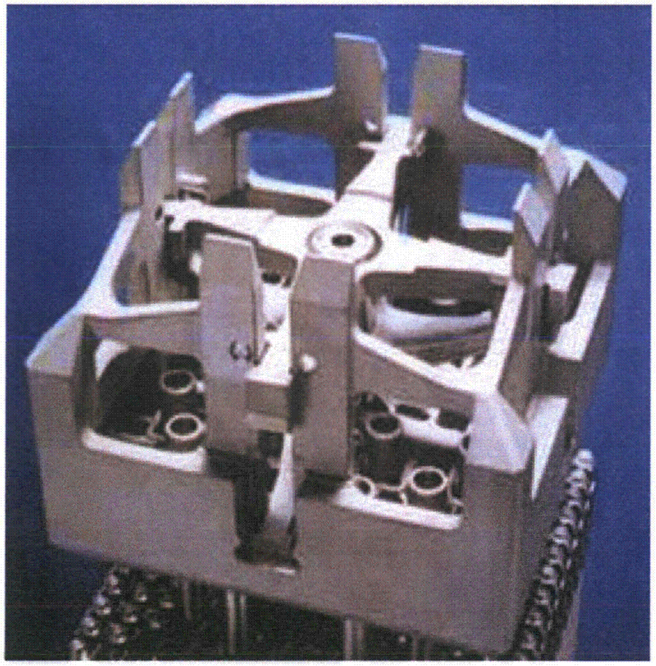
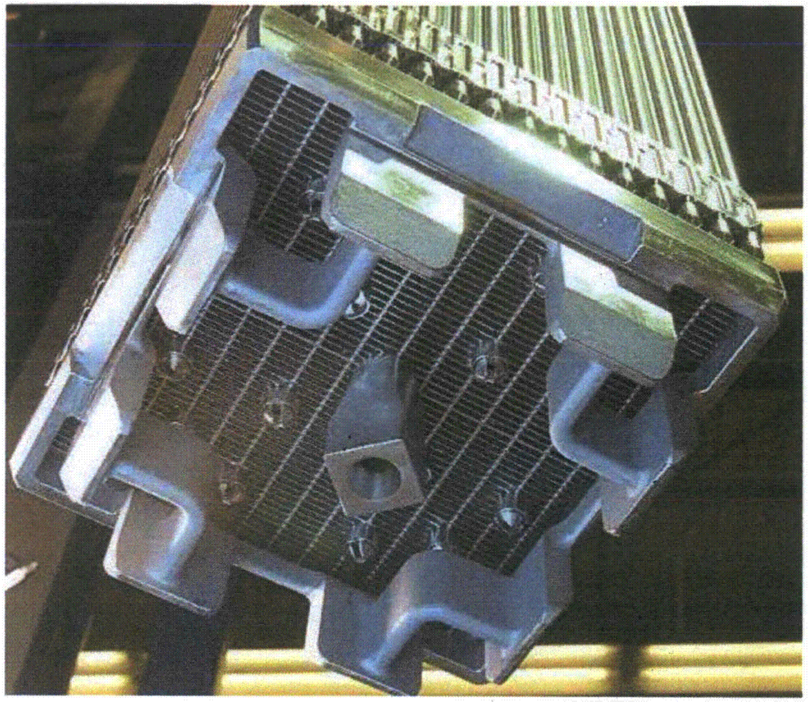
Mark-B-HTP Design





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US PWR Fuel Designs – Mark-B-HTP Planned Design Transitions

Babcock & Wilcox Reactor Type – Issues and Solutions

- **Fuel Assembly - Baffle Interaction**
  - **Transition to Mark-B HTP Fuel Assembly**
- **Thermal Margin and CRUD mitigation**
  - **Improvement evaluations initiated in Fall 2010**
    - Level III CRUD evaluation completed
    - Evaluation of addition of IFM Grids
- **PCI Margin**
  - **Chamfered Pellet**
- **Transition Status:**
  - **Chamfered Pellet implementation beginning mid 2011**
  - **Improvements based on evaluations (IFM Grids) beginning 2012**

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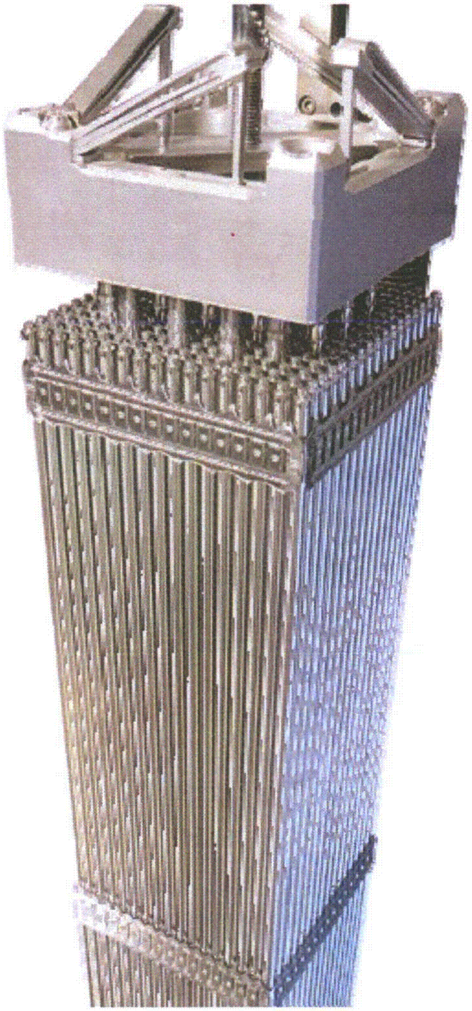
Mark-BW and W-HTP Designs



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US PWR Fuel Designs – Mark-BW and W HTP Planned Design Transitions

Westinghouse Reactor Type – Issues and Solutions

- Fuel Assembly Distortion
  - Welded Structure
  - MONOBLOC Guide Tube
  - HTP Spacer Grids
  - HMP Bottom Grid
- Fuel Rod Bow
  - HTP Spacer Grids
  - HMP Bottom Grid
- Cross Flow / Grid to Rod Fretting
  - HTP Spacer Grids
  - HMP Bottom Grid
- Power Uprates / PCI Margin
  - M5 Cladding (also support of advanced fuel management and high rod duty)
  - Chamfered Pellet
  - IFM Grids

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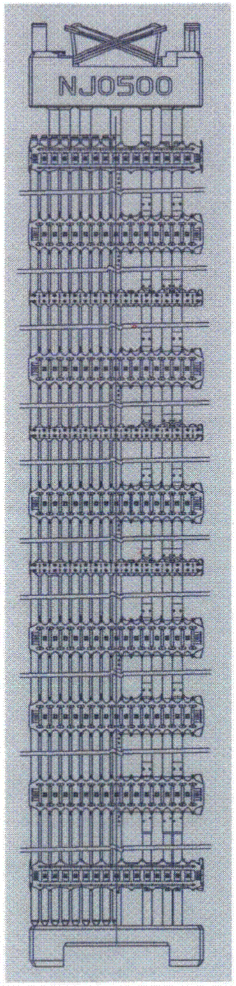
Mark-BW Planned Design Transitions – Sequoyah Units 1 and 2

Mark-BW (Current)

- *Inconel Mark-BW Upper Grid*
- *Swaged Guide Tube*
- *Floating Structure*
- *No Mid-Span Mixing Grids*
- *6xZr-4 Mark-BW Spacer Grids*
  - *5x Vaned*
  - *1x Non-Vaned*
- *Inconel Mark-BW Bottom Grid*
- *CM TRAPPER™ Lower End Fitting*



W17 HTP (Future)

- *Zr-4 HTP Upper Grid*
- *MONOBLOC™ Guide Tube*
- *Welded Structure*
- *3x Zr-4 IFM Grids*
- *6x Zr-4 HTP Spacer Grids*
- *Inconel HMP Bottom Grid*
- *FUELGUARD™ Lower End Fitting*

Target W HTP Design - Reload introduction in Fall 2012

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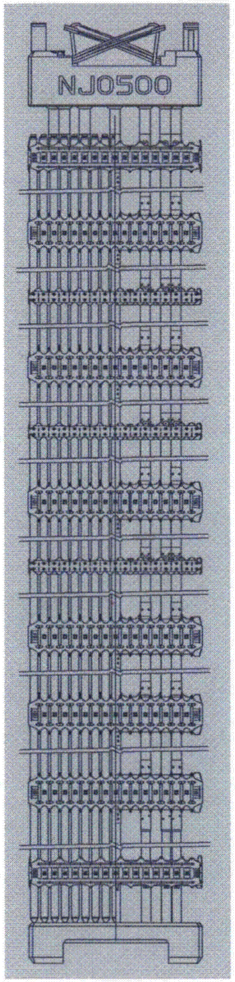
W17 HTP Planned Design Transitions – Harris

W17 HTP (Current)

- *Bi-Metallic Upper Grid*
- *Swaged Guide Tube*
- *Zr-4 Cladding*
- *Standard Pellet*
- *Bi-Metallic Bottom Grid*

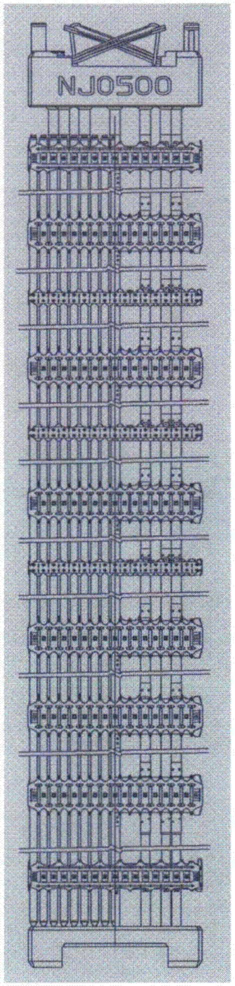


W17 HTP (Future)

- *Zr-4 HTP Upper Grid*
- *MONOBLOC™ Guide Tube*
- *M5 Cladding*
- *Chamfered Pellet*
- *Inconel HMP Bottom Grid*

Intermediate Step - Reload introduction in early 2012

W15 HTP Planned Design Transitions – Robinson



W15 HTP (Current)	***W15 HTP (Future)***
Swaged Guide Tube	***MONOBLOC™ Guide Tube***
Zr-4 Cladding	***M5 Cladding***
Standard Pellet	***Chamfered Pellet***
Bi-Metallic Bottom Grid	***Inconel HMP Bottom Grid***

» Reload introduction in Fall 2011

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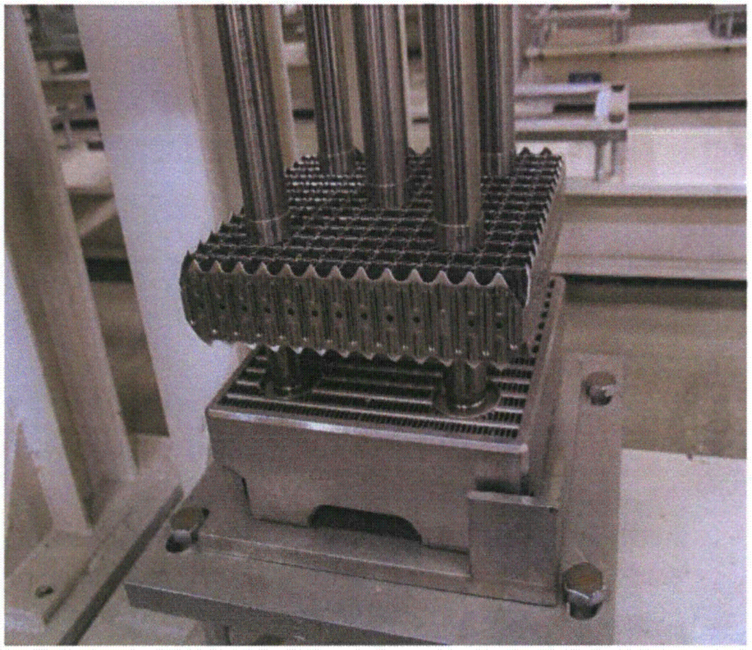
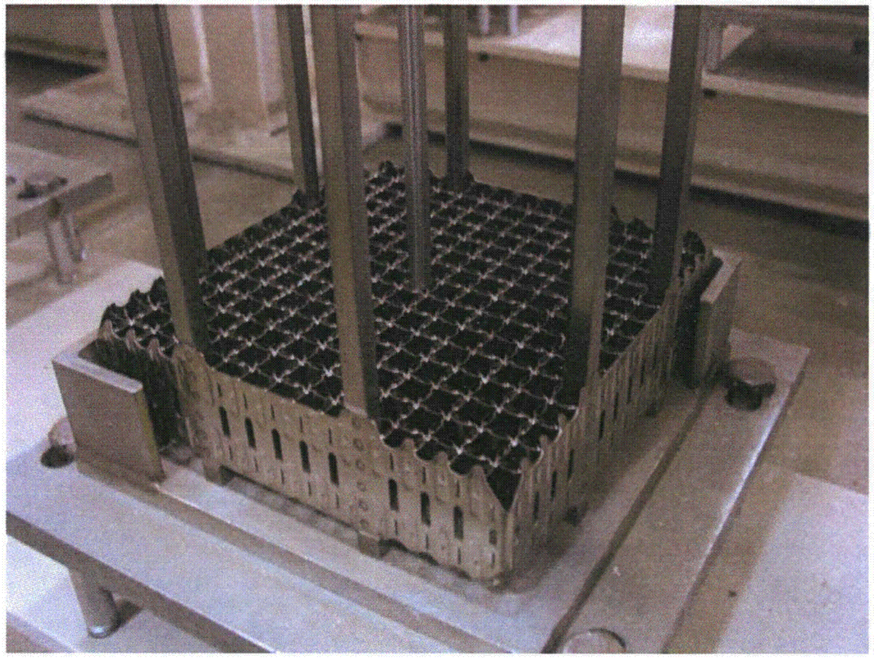
CE HTP Design

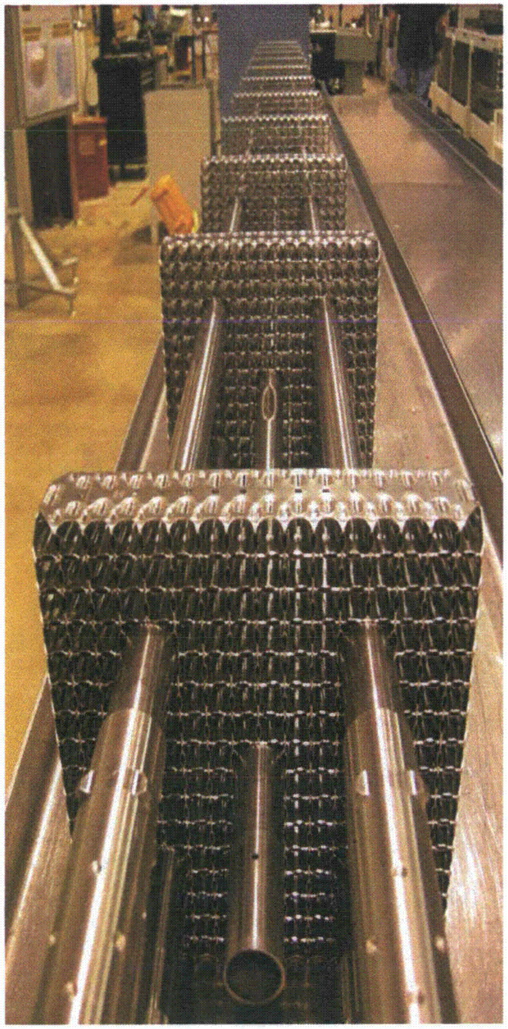
CE 14x14

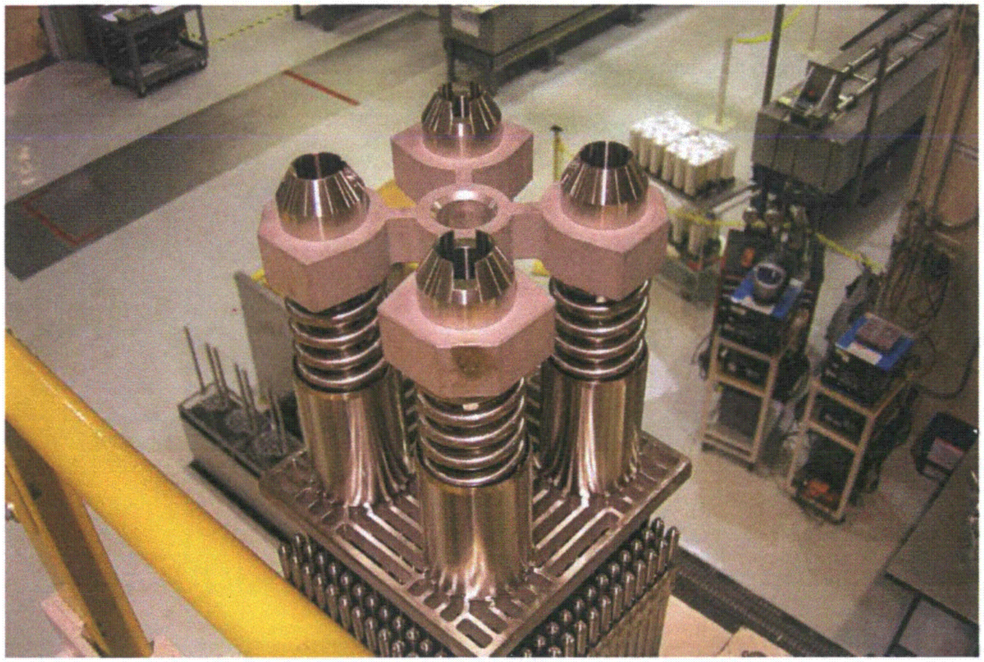


CE 15x15



CE HTP Design 16 x 16





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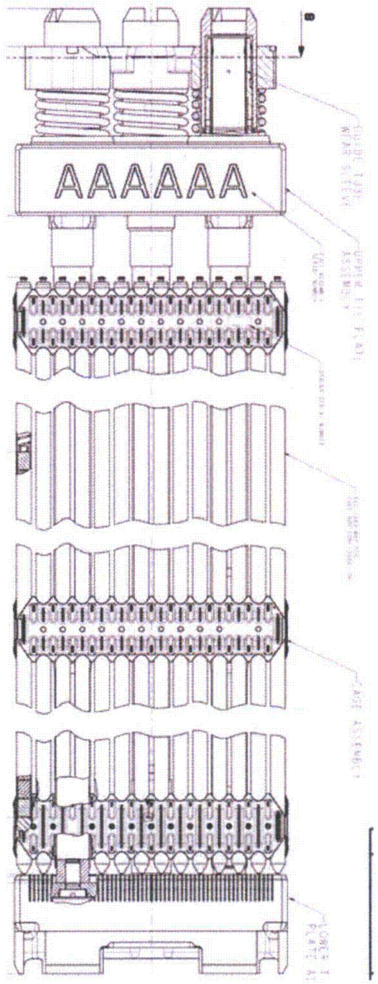
US PWR Fuel Designs – CE HTP Planned Design Transitions

Combustion Engineering Reactor Type – Issues and Solutions

- Cross Flow / Grid to Rod Fretting
  - HTP and HMP spacer grids
- CRUD Formation Resistance
  - IFM Grids
- Seismic Robustness
  - HTP/HMP spacer grids
  - thicker HTP outer strap
  - thicker guide tube wall
- Power Uprates / PCI Margin
  - IFM Grids
  - Chamfered Pellet

CE14 HTP Planned Design Transitions – SLU1, MIL1, CCL 1&2



CE14 HTP (Current)

- ***Drawn Guide Tube***
- ***Zr-4 Cladding***
- ***Standard Pellet***

CE14 HTP (Future)

- ***MONOBLOC™ Guide Tube***
- ***M5 Cladding***
- ***Chamfered Pellet***

» **Reload introduction of Advanced CE HTP fuel initiated at CCL1 in early 2011**

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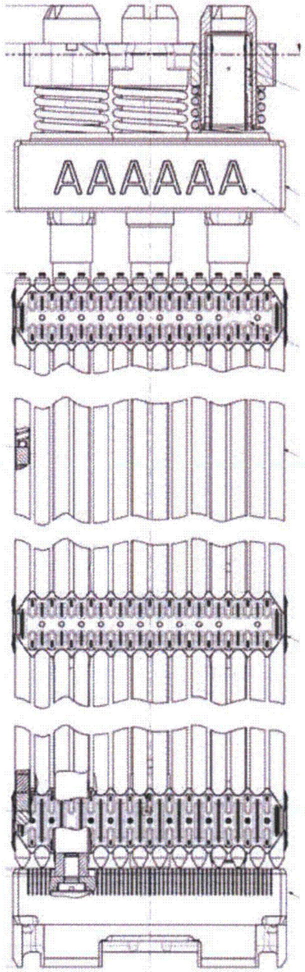
PWR Fuel Planned Design Transition – CE16 HTP (Palo Verde , SONGS)



CE16 HTP (Current)

- MONOBLOC™ Guide Tube
- 10x Zr-4 HTP Spacer Grids

C16 HTP (Future)

- MONOBLOC™ Guide Tube with Optimized Thickness
- 10x Zr-4 HTP Spacer Grids with Optimized Side Plate Thickness

» Mini-Batch introduction in Fall 2012

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Lead Assembly Programs

CE Lead Assembly Programs

- **16x16**
  - **Palo Verde**
    - Eight lead assemblies built/shipped 2008.
    - All-M5 bundle design (clad & structure)
    - Four corner guide tubes - double-dashpot MONOBLOC™ design.
    - Center guide tube w/ large dimples for instrumentation guidance
  - **SONGS**
    - Eight lead assemblies shipped in 2009
    - Single dashpot guide corner tubes
    - Non-dimpled center guide tube
- **14x14**
  - **2 Lead Assemblies at Calvert Cliffs, irradiated through 3 cycles**
  - **Discharged fall 2010**

PWR Core Engineering Methods

Tom DeLorey
Manager, Neutronics – PWR Fuel

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Overview

- Code System Updates
- Code Topical Reports
- Implementation Objectives
- Implementation Topical Reports

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Core Engineering Codes

- Neutronics: APOLLO2-A / ARTEMIS
- Thermal Hydraulics: COBRA-FLX
- Fuel Rod: COPERNIC3
- Automation / Interface: "LADON"

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Challenging Development Targets

► **Development of one of the world's leading industrial code systems for LWR fuel assembly and core design as well as safety analyses**

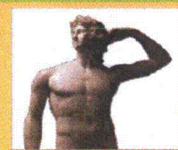
- **State of the art in physical modeling, numerical performance, user interface, and software engineering**
- **Maximum flexibility with respect to accuracy and performance**
  - **From: Reference capability**:
    pin-by-pin, multigroup, transport theory, detailed nuclide chain, detailed thermal-hydraulics and thermomechanics
  - **To: Scoping capability:**
    2 energy groups, diffusion theory, optimized nuclide chain, simplified thermal-hydraulics and thermomechanics
- **Extensive verification and validation base for efficient licensing and broad acceptance by internal and external users worldwide**

Business and Integration Services
LADON

Spectral Code System

XS Library Generator
CLARUS

Spectral Code
APOLLO2-A



Core Simulator System

Cross Section Evaluation
HERMES

Thermal-hydraulics Module ***THM***
(COBRA-FLX)

Core Simulator
ARTEMIS™

Fuel Assembly Inventory
POSEIDON

Thermal-mechanics Module
FRM

On-line Core Monitoring

3D Power Density Reconstruction Technique

ARGOS

Core Simulator
ARTEMIS™

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APOLLO2-A
Lattice Physics Code

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Lattice Physics Code

- **APOLLO2-A: the lattice-physics code of the ARCADIA® System**
  - **Steady state 2D multi-group transport equation for neutrons and gammas on fuel assemblies and color-sets using MOC for Master Flux Computation**
  - **APOLLO2-A is the AREVA industrial version of APOLLO2.8 code**
    - Developed by French "Commissariat à l'Energie Atomique" (CEA) research laboratory
    - Provides fundamental computation modules
  - **Adapted by AREVA for PWR & BWR industrial applications**
    - Appropriate methodology (Calculation Scheme) for PWR lattices
    - Industrial Front-End
    - Comprehensive Verification and Validation Base
  - **It uses a 281-group library based on JEFF3.1 evaluation**
  - **With a double purpose**
    - Generation of neutronic fuel assembly data for 3D neutronic core simulators (ARTEMIS)
    - Standalone design studies (fuel assembly-related)

ARTEMIS

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Proprietary

Core Simulator ARTEMIS Main Features

- Flexible nodal 3D multigroup diffusion and SP_N transport solution from coarse mesh to pin-by-pin
- Stand-alone neutronics and coupled with thermal-hydraulics/ thermal-mechanics
- Cross section representation continuous from cold (room temperature) to hot conditions
- One code for steady-state and transient applications
- Possibility for parallelization of the entire program
- Further developed flux solution numerics for improved performance and robustness as well as enhanced iteration stability
- New software architecture – model driven approach with UML (Unified Modeling Language)

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LADON

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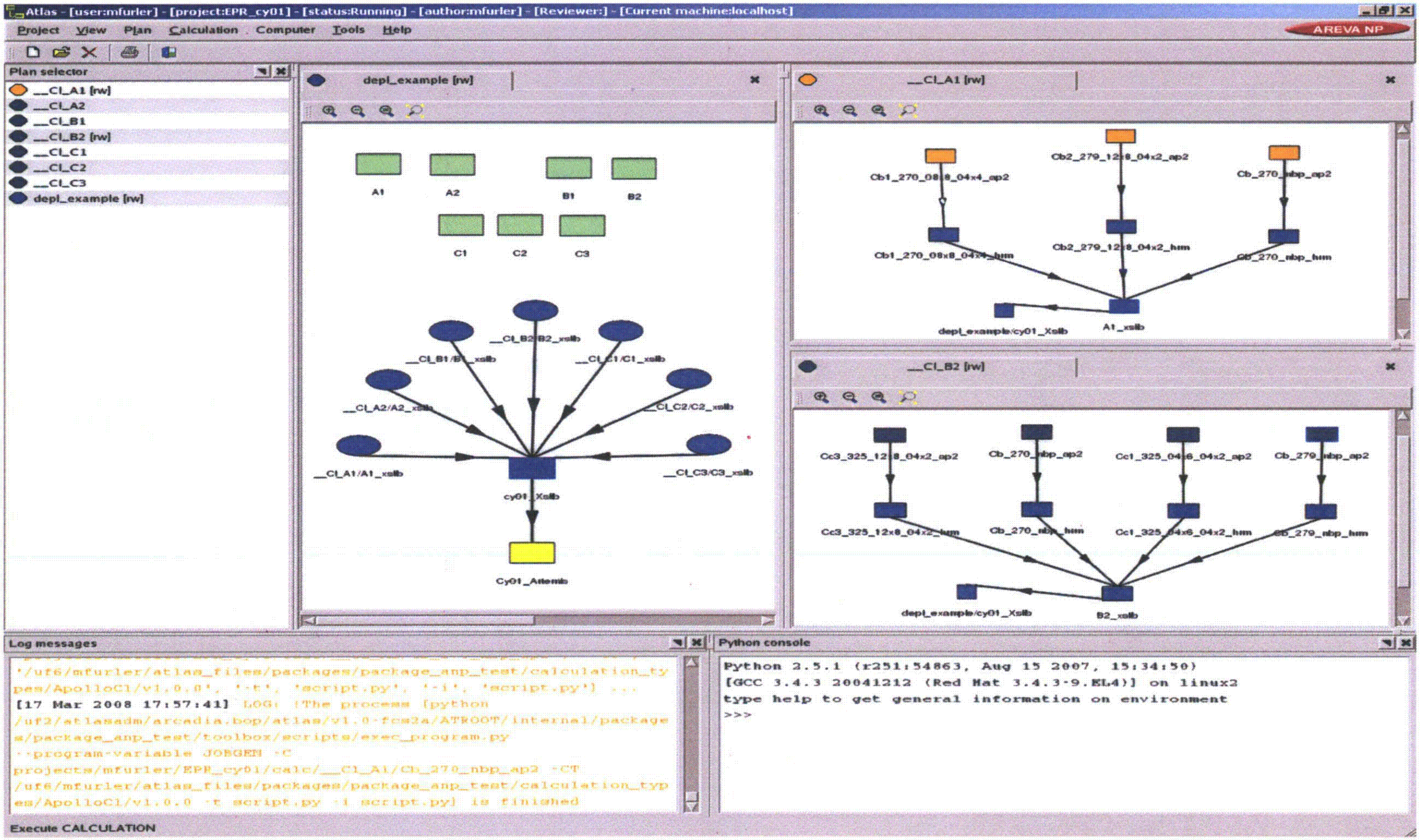
LADON–Integration and Business Services
ATLAS Status



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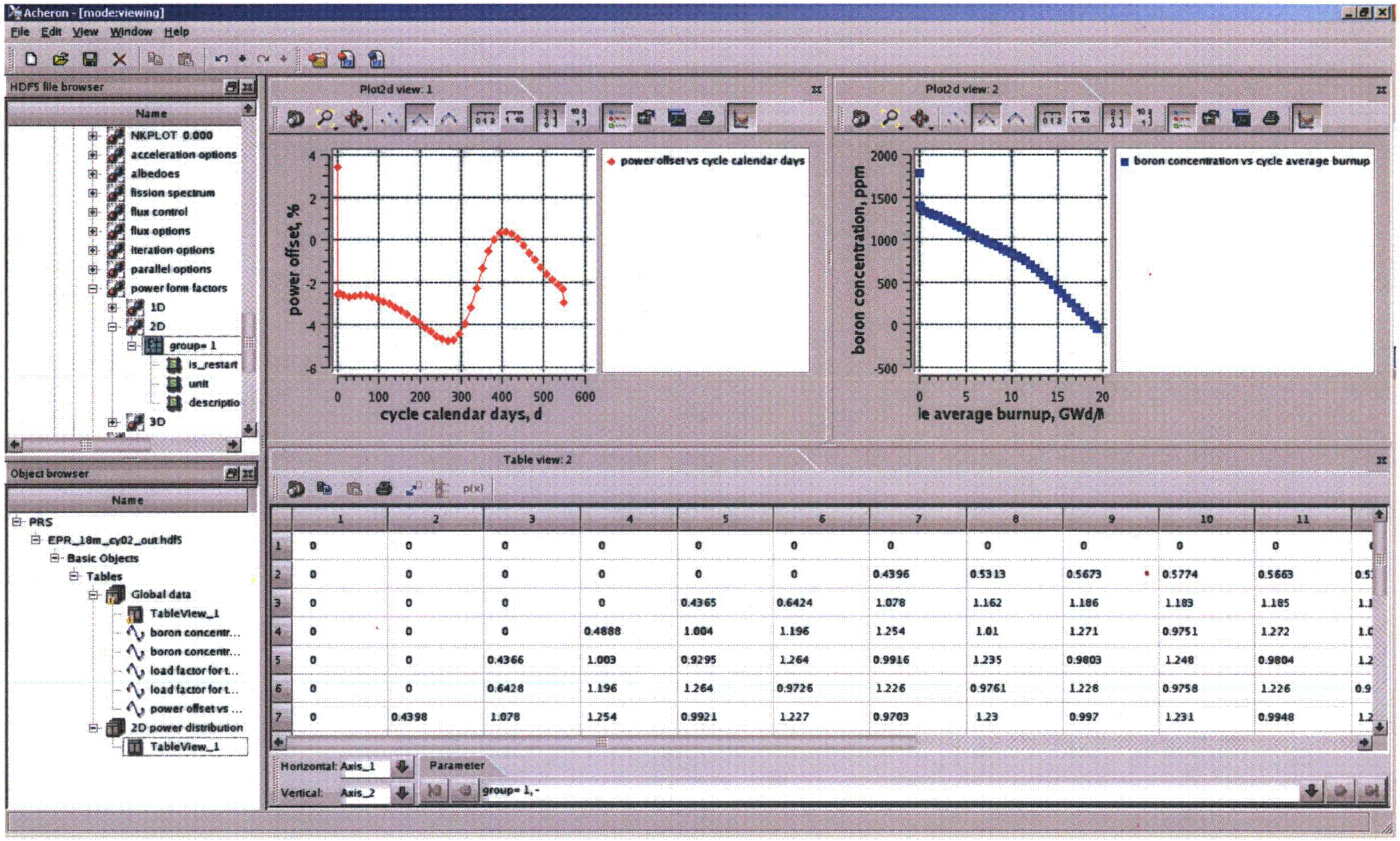
LADON–Integration and Business Services
ACHERON



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COBRA-FLX

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Purpose of a Global Converged T-H Code

- The COBRA-FLX code will be used for applications associated with licensing safety-related analyses and for operational issue analyses.

  Examples include:

  - DNBR predictions (steady-state and transient conditions) using approved CHF correlations along with full core subchannel by subchannel calculations
  - flow redistribution analyses (full core and mixed core conditions) for quantifying crossflow velocities
  - coupled capability for coolant condition feedback for neutronic calculations
  - axial pressure drop predictions for hydraulic lift force determinations (for fuel assembly hold down requirements and core internals force analyses)
  - understanding and predicting impacts of operational phenomena, like:
    - CIPS/CILC risks
    - establishing local boundary conditions for subsequent CFD analyses to examine local effects

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COBRA-FLX Coupling in ARTEMIS

- COBRA-FLX is an integral part of the core simulator ARTEMIS. ARTEMIS is the core simulator of the ARCADIA code system.
- COBRA-FLX can be applied within ARTEMIS in many flexible ways:
  - ◇ It can be called without any coupling to other ARTEMIS models
    ⇨This is the subject of the COBRA-FLX Topical Report

  In addition

  - ◇ It can be coupled with the ARTEMIS fuel rod model
  - ◇ It can be coupled solely with the ARTEMIS neutron physics model (coarse meshing, moderator thermal dynamic conditions from COBRA-FLX)
  - ◇ It can be coupled with the ARTEMIS neutron physics model (coarse meshing) and the ARTEMIS fuel rod model

    ⇨This is the subject of the ARCADIA Topical Report

COPERNIC3

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COPERNIC3 Development

[ ]

Code Topical Reports

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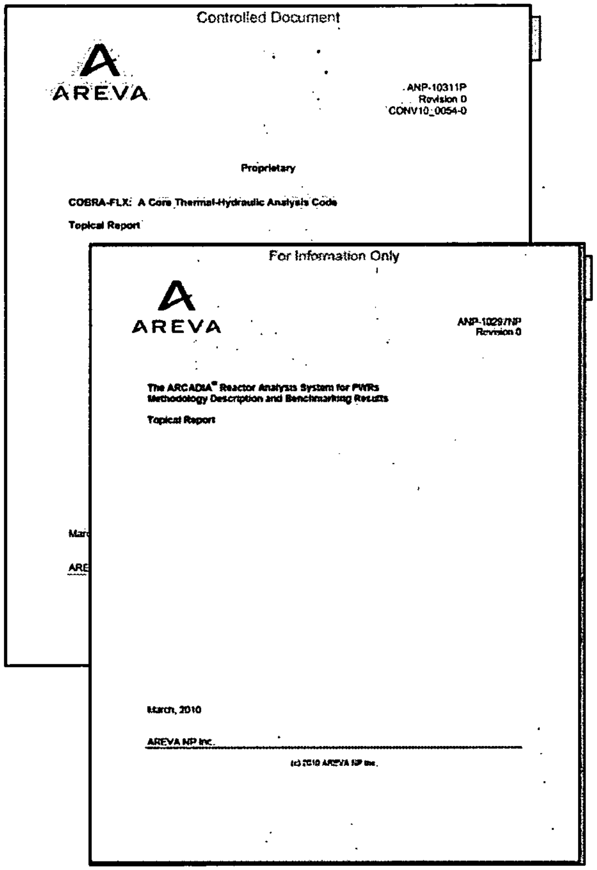
Status of ARCADIA® Development


Controlled Document

AREVA

ANP-10311P
Revision 0
CONV10_0054-0

Proprietary

COBRA-FLX: A Core Thermal-Hydraulic Analysis Code

Topical Report

For Information Only

AREVA

The ARCADIA® Reactor Analysis System for PWRs
Methodology Description and Benchmarking Results

Topical Report

March, 2010

AREVA NP Inc.

Submittal of 2 Topical Reports:

The ARCADIA® Reactor Analysis System for PWRs Methodology Description and Benchmarking Results Topical Report (Submitted March 2010)

COBRA-FLX: A Core Thermal-Hydraulic Analysis Code (in concurrence)

COPERNIC3 (Submittal August 2012)

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Implementation Strategy

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Fuels Methods Implementation

- AREVA's intent is NOT to simply replace old codes with new codes
- New methodologies being developed with the goals of:
  - Taking advantage of new code features (e.g. full core DNB evaluation coupled with neutronics calculation)
  - Taking advantage of best practices from US, French, and German experience
  - Full consideration of SRP guidance and clear traceability
  - Simplification of Topical Report structure, reduction in the number of topical reports
  - Facilitate future methods upgrades
  - "Convergence" : one set of US methods, global convergence where advantageous

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Fuels Methods Implementation

- AREVA's strategy is to implement for the CE/W market first, then extend to the B&W market
- If a contract is placed with DOE for the development of MOX methods, AREVA will develop ONE set of topical reports that cover UO2 and MOX for CE and W plant types
- Expected topical reports:
  - ◇ Reload Analysis Topical
  - ◇ Power Distribution and Control
  - ◇ Rod Ejection
  - ◇ Rod Swap
  - ◇ CE/W Setpoint Methodology
  - ◇ Rod Bow / Assembly Bow
  - ◇ Fuel Assembly Repair / Reconstitution
  - ◇ Fuel Assembly Design

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BWR Fuel Design Update

Norman L. Garner
Technical Sales Manager – BWR Fuel

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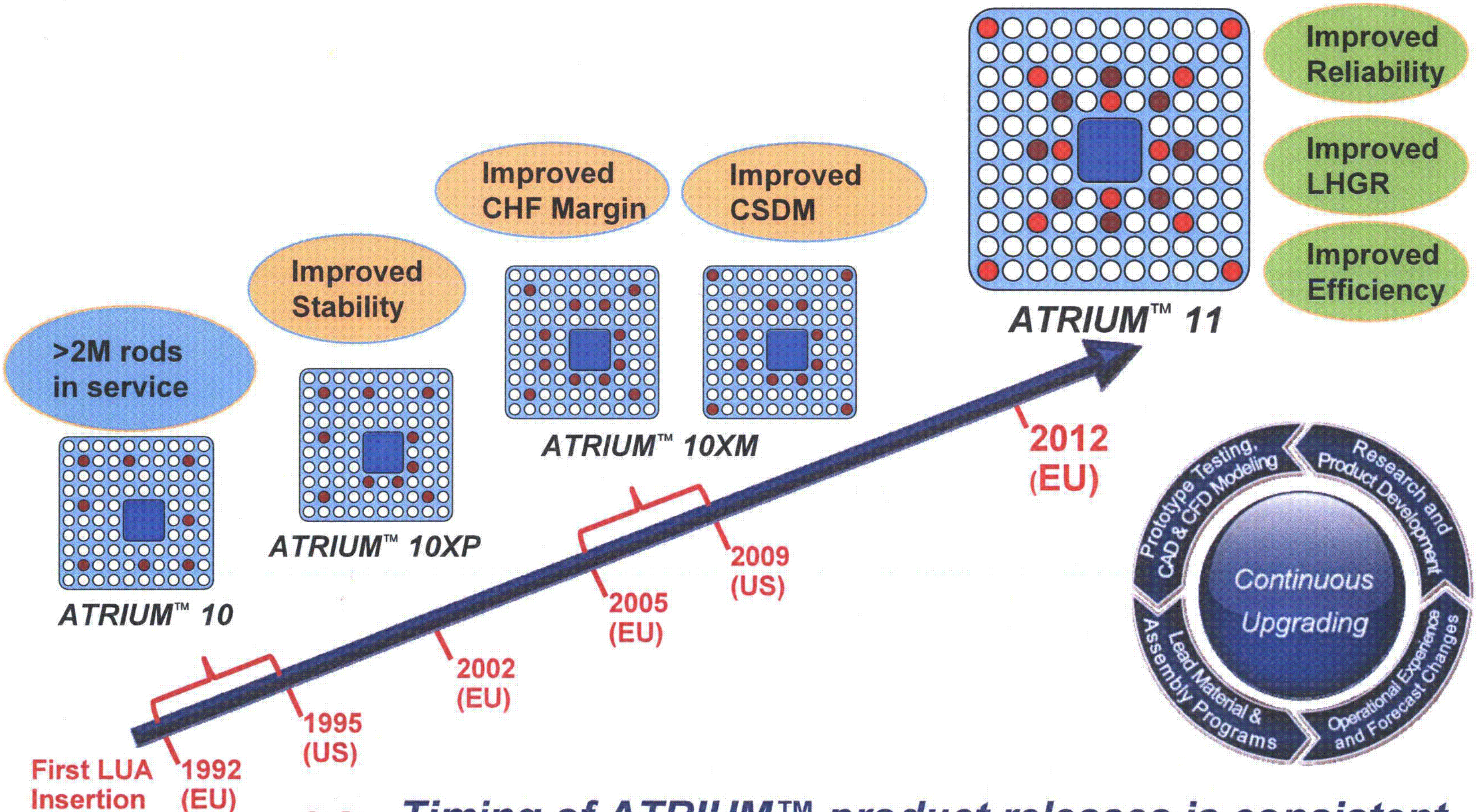
AREVA BWR Product Design Topics

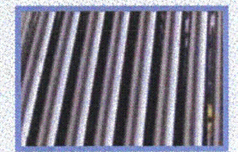
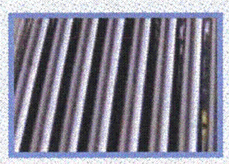
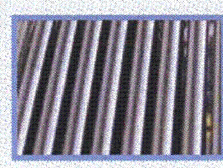
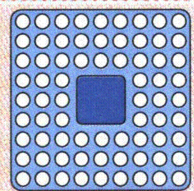
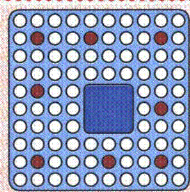
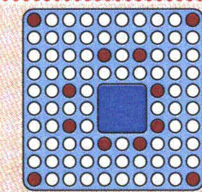
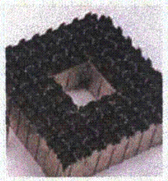
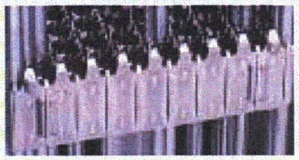
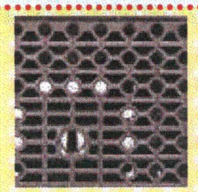
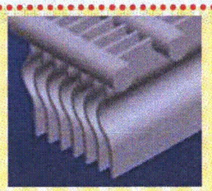
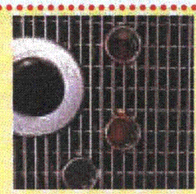
- ATRIUM™ Product Family & Product Mix
- ATRIUM™ 10XM U.S. Introduction
- ATRIUM™ 11 Development Update

AREVA has extended the ATRIUM™ concept into a family of BWR fuel products



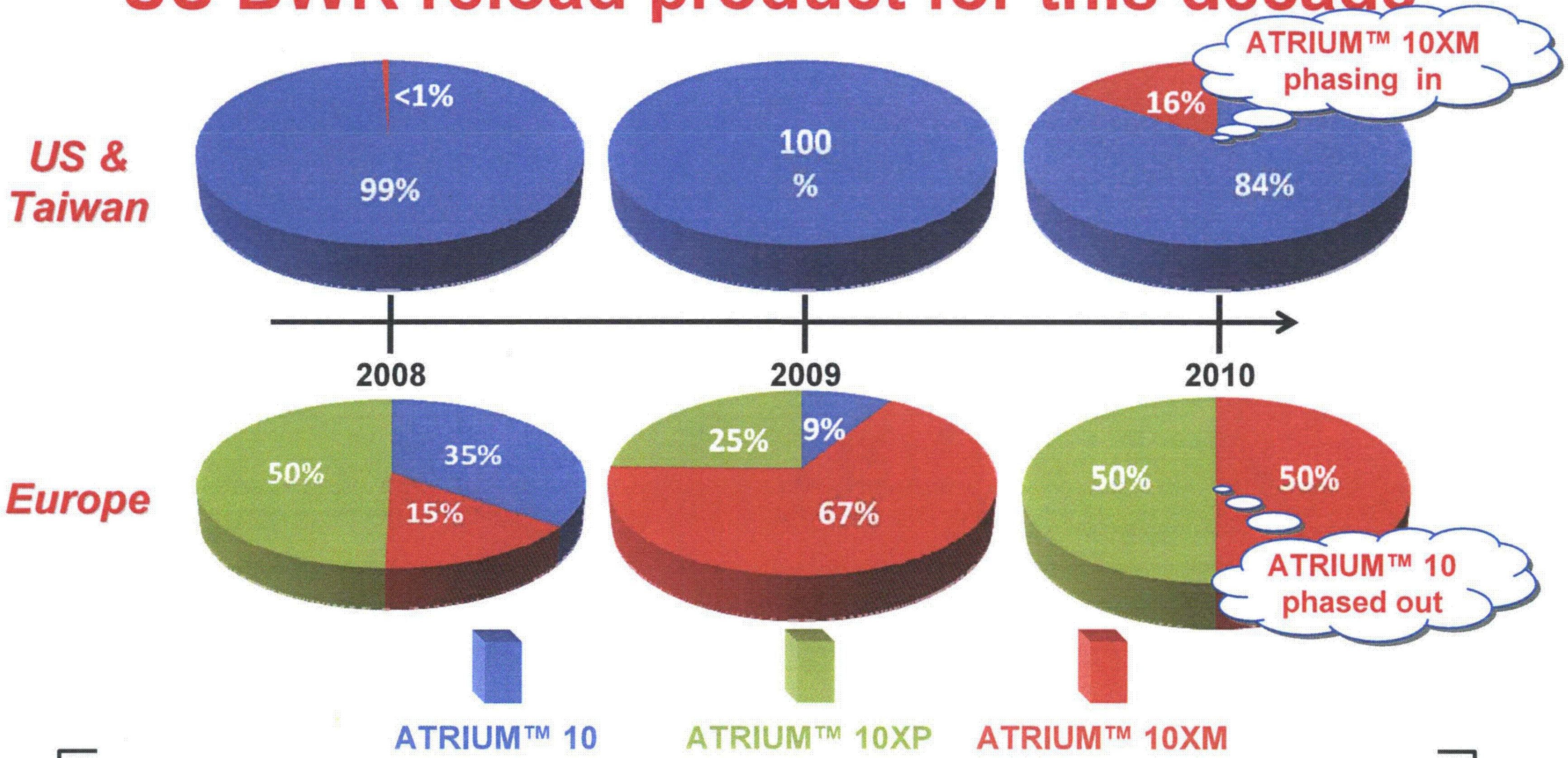
» *Timing of ATRIUM™ product releases is consistent with industry needs and operating strategies*

"New" ATRIUM™ 10XM features are directly linked to previous designs

	ATRIUM™ 9	ATRIUM™ 10	ATRIUM™ 10XM	
Fuel Rod				▶ New Optimized diameter ▶ *Unchanged Cladding thickness-to-diameter ratio*
Lattice				▶ New Optimized array ▶ *Unchanged ATRIUM™ structure*
Spacer				▶ New all Ni alloy construction ▶ *Unchanged ULTRAFLOW™ rod support & mixing vanes*
Debris Filter				▶ New Improved FUELGUARD™ ▶ *Unchanged curved blade non-line-of-sight feature*

» ***Continuity in design provides for reliable, predictable behavior, stable manufacturing and reduced time-to-market***

ATRIUM™ 10XM is AREVA's primary US BWR reload product for this decade



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ATRIUM™ 11 Development

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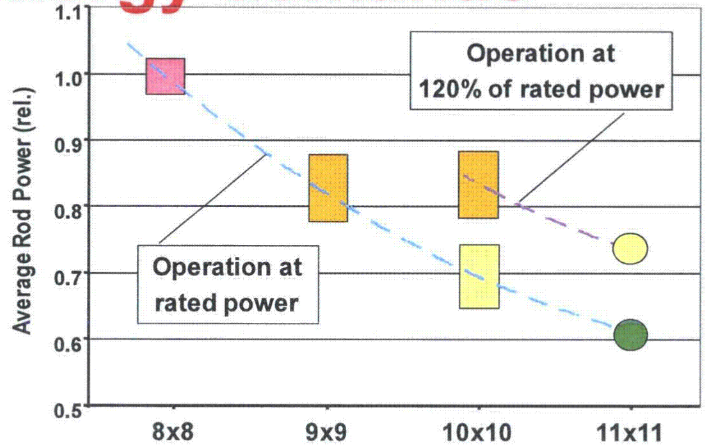
The ATRIUM™ 11 has been developed to respond to increased BWR energy demands

- Significant reduction in linear heat generation rate
- Margins for extended power uprate
- Margins regarding reliability
- Better fuel utilization



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AREVA is executing a disciplined process to ready the ATRIUM™ 11 for reload supply

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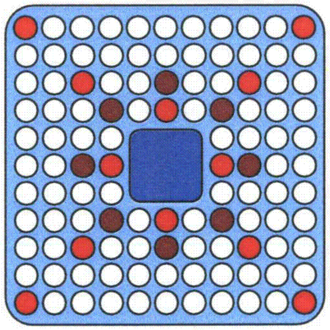
ATRIUM™ 11 Design Overview: Key Design Features

improved reliability

improved LHGR

improved efficiency

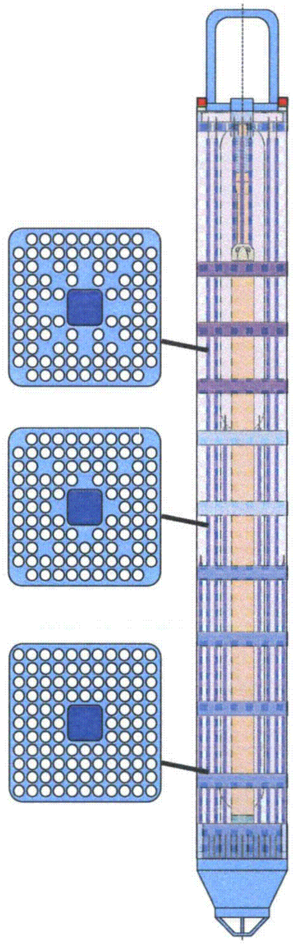


ATRIUM™ 11

12 Short PLFR

8 Long PLFR

- Symmetric 11x11 lattice
- Familiar ATRIUM™ tie structure
- Multiple length PLFRs
- Reduced mass, alloy 718 ULTRAFLOW™ spacers with debris resistant features
- 3rd Generation FUELGUARD™ debris filter
- Low ΔP Upper Tie Plate
- Advanced fuel channel with distortion resistant features



The ATRIUM™ 11 spacer builds on the proven ULTRAFLOW™ design with enhanced features

The ATRIUM™ 11 continues the practice of avoiding structural loads on fuel rods

- Central, ATRIUM™ load bearing water channel
- Familiar quick release UTP mechanism retained from previous ATRIUM™ products
- Water channel wall thickness increased to maintain static stress load within experience
- Fabricated from Zry-BWR

[ ] [ ]

The ATRIUM™ 11 lower tie plate enhances debris filtering and core loading ease

- **3rd Generation FUELGUARD™ debris filter**
  - Debris exclusion target conservatively scaled with rod pitch
  - No paths for debris to bypass inlet filter
- **Load transfer interface with water channel unchanged from preceding ATRIUM™ designs**
- **Steep angle of 4-bail centering guide improves positioning of bundle during core loading**

[ ]

[ ]

The ATRIUM™ 11 upper tie plate supports enhanced stability plus debris protection

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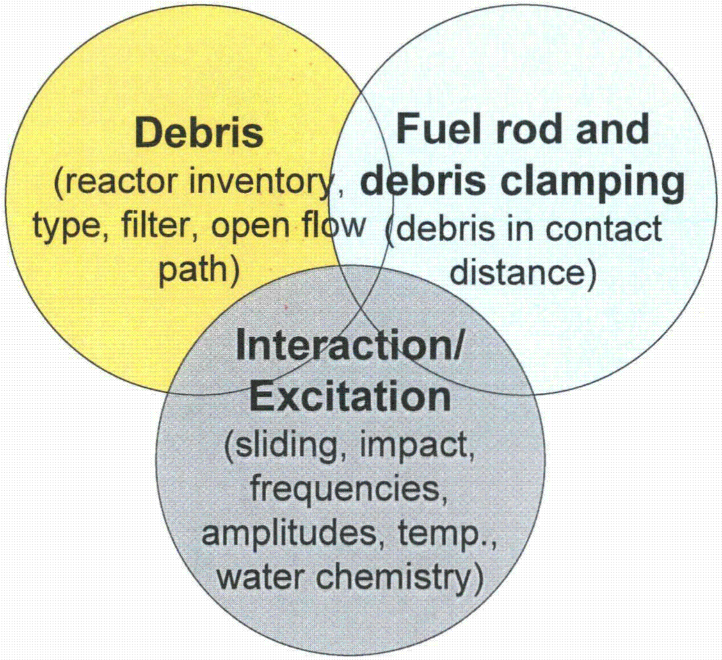
The ATRIUM™ 11 fuel channel enhances operational stability

- Fuel channel remains a separable component installed on fuel assembly either at the reactor or the fuel fabrication plant
  - Retains preceding Advanced Fuel Channel (AFC) exterior geometry

Significant progress has been made in conducting ATRIUM™ 11 design verification testing

[ ]

Comprehensive debris resistance is a key element of ATRIUM™ 11 design objectives



The ATRIUM™ 11 is designed to provide a comprehensive defense against debris failure

Extensive testing has verified the targeted debris filtering efficiency was realized

[ ]

ATRIUM™ 11 manufacturability has been proven through fabrication of test bundles

[ ]

The ATRIUM™ 11 design retains proven core interface features of preceding designs

[ ]

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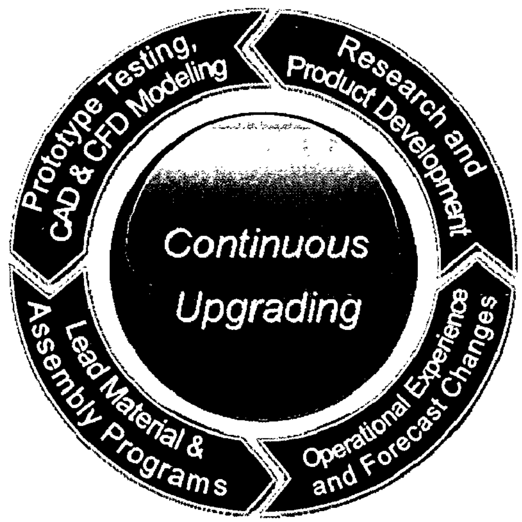
Extensive instrumentation was incorporated into the ATRIUM™ 11 critical power test bundle

[ ]

The ATRIUM™ 11 LUA fabrication and licensing effort is well underway

AREVA is leading the way with reliable and high performance BWR fuel products

- The ATRIUM™ 10XM product is mature and is being supplied in reload quantities
- The ATRIUM™ 10XM is designed to be responsive to limiting criteria for uprated 18 to 24 month cycles
- The ATRIUM™ 11 development project is now proceeding to the LUA stage



» ***AREVA is committed to developing fuel for tomorrow's needs while bringing timely advances to today's BWR fuel market***

BWR Codes and Methods Development

Douglas Pruitt
Manager/FDT-AR

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Agenda

- Current Methods
- Methodology Evolution
- AURORA-B Road Map
- Additional Methodology Development
- ACE Correlation
- Conclusions

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AREVA NP's BWR Methodologies
Current Status

Mechanical **Neutronics** **Safety & Licensing**

* Codes being replaced by new methods

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BWR Methodology Evolution

- Last major code evolution was associated with the introduction of MICROBURN-B2, RAMONA5-FA and RODEX4
- Major renovation of BWR Safety Analyses methods has been underway for the last 8 years

[ ]

- Submittal of the deterministic AURORA-B AOO methodology was the first step in this renovation

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AREVA NP's US BWR Methodologies Next Evolutions

Mechanical | **Neutronics** | **Safety & Licensing**

* Improved methods recently submitted

** New C&M currently being developed

AURORA-B

AREVA's Realistic BWR Transient Simulator

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AURORA-B Platform

- Advanced, realistic BWR transient simulator
  - Eliminates legacy codes → Licensing and Operational Limits
  - Wide range of applicability → Licensing and Operational Support
  - Up-to-date code benchmarking and validation → Latest Understanding
  - Modern methodology development principles

- A best estimate multi-physics code system for simulating the coupled fuel, neutronic, and thermal hydraulic BWR system response
  - RODEX4 best estimate fuel performance predictions
  - MB2-K 3D kinetics built upon MICROBURN-B2
  - S-RELAP5 modern two-fluid T/H system code

» **Consolidation of experience and a fundamental shift for the future**

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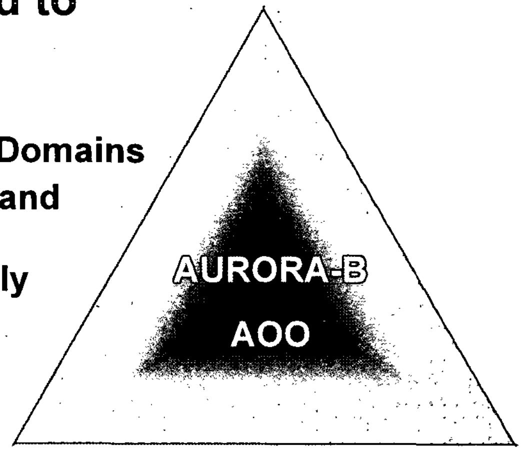
AURORA-B
AOO Licensing Topical Report

- The AURORA-B AOO methodology was a global project involving engineers from Richland, San Jose and Erlangen
- The AURORA-B AOO methodology was submitted to the NRC
  - Applicable to all forced circulation BWR plants
  - Applicable to Extended Power Uprate and Extended Flow Domains
  - Included data to assess all the improved physical models and new/revised component models
  - Included separate effect and integral tests to validate highly ranked phenomena
- Requested approval for evaluation of
  - Transient minimum MCPR
  - Peak primary system pressure
  - Evaluation of fuel integrity PCT criteria
  - Evaluation of thermal-mechanical criteria w/RODEX4
- and is currently under NRC acceptance review



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AURORA-B AOO Technical Capability Comparison

[ ]

» **AURORA-B establishes general BWR capabilities with solid physics basis, extensible to future methodologies**

AURORA-B
Development Focus

- Immediate development activities are driven by evolving Regulatory requirements and market forces [ ]

[ ]

AURORA-B Extensions

- Two concurrent development activities are driven by evolving Regulatory requirements and market forces (advanced designs / materials)

[ ]

- Goal: Address Regulatory concerns over operational range

AURORA-B Extensions

AURORA-B Extensions

AURORA-B Extensions

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AURORA-B Development Plan

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Conclusions

- The submittal of AURORA-B represents the first step in BWR transient and accident renovation
  - Composed of well qualified and approved modules (S-RELAP5, MB2-K, RODEX4)
  - Extensive qualification database
- Incremental refinement and qualification of the base AURORA-B models will extend its applicability to additional transient and accident scenarios

[ ]

- BWR renovation facilitates the retirement of current BWR transient and accident methodologies

Additional Methodology Development

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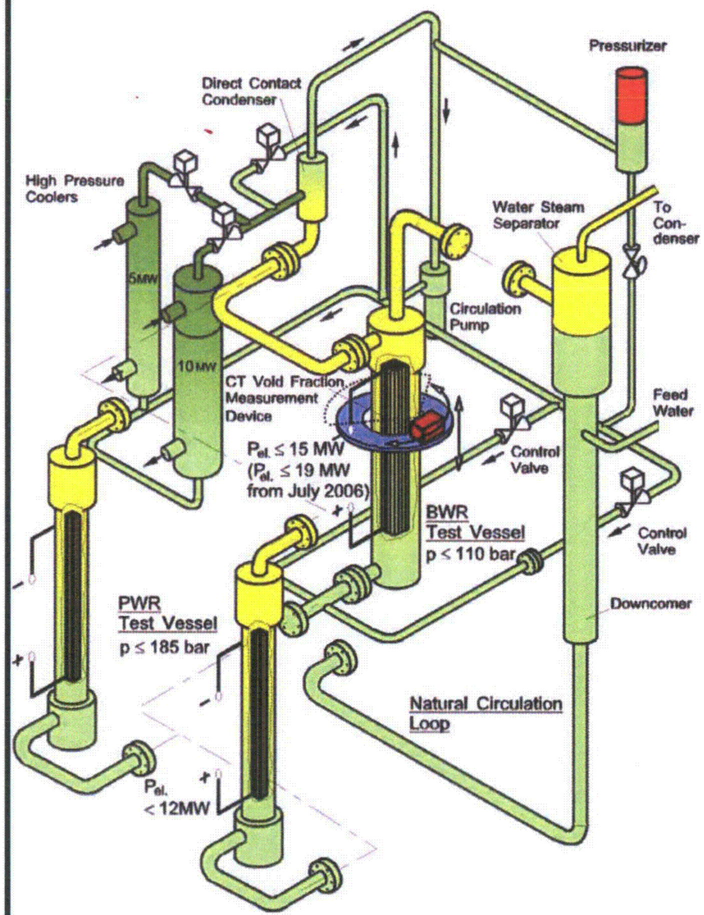
Additional Methodology Development

[ ]

Additional Methodology Development
Testing History

[ ]



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Additional Methodology Development
Testing History

Additional Methodology Development Testing Advantages

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BWR Codes & Methods

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ACE Correlation

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ACE Correlation

[ ]

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ACE Correlation

ACE Correlation

[ ]

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Conclusions

- AREVA has been and continues to actively develop advanced methods to provide a strong physical basis in support of both customer and regulator actions
- AREVA expands typical industry experimental investigations to support significant steps forward in understanding of underlying physical phenomena
- AREVA will be submitting a number of topical reports in the next few years to retire our current legacy codes in a stepwise fashion
- AREVA will value pre- and post-submittal meetings as appropriate to facilitate the regulatory review process

BWR Operating Experience Update

Norman L. Garner
Technical Sales Manager – BWR Fuel

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AREVA BWR Operating Experience Topics

- 2010 & 2011 PIE Campaigns
- BWR Fuel Reliability Update
- Advanced Product and Material R&D
- Enhanced Core Monitoring Update

A significant number of BWR fuel examinations were made in 2010

[

]

The 2010 BWR PIE campaigns yielded a number of notable results

[ ]

Planned 2011 BWR PIE campaigns will obtain important performance data

[ ]

A significant number of BWR fuel examinations are planned for 2011

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Fuel rod reliability of AREVA US-fabricated BWR fuel (for US and Taiwan) is near 100%

- Averaging one failed fuel rod per year over past five years

[ ]

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AREVA is continuing to aggressively pursue root cause for all BWR failures globally

[ ]

Advanced analyses showed low probability of PCI failure for US rods examined in Q1 2011

[ ]

Recent examinations looked at each of the three failed rods detected in past three years

[ ]

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BWR Advanced Product and Material R&D

AREVA BWR R&D programs are pursuing both near and long term objectives

[ ]

Near term R&D is aimed at qualifying new materials for reload applications

[ ]

Long term material R&D will identify candidate alloys for future applications

[ ]

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AREVA is working with the BWR industry to better understand channel bow mechanics

- **EPRI-sponsored study of hydrogen effect on fuel channel material growth at the Advanced Test Reactor in Idaho**
  - AREVA is contributing fuel channel material and will support evaluation of results
  - Specifically looking at influence of hydrogen on growth rates
- **NFIR Channel Distortion Project (NFIR VI, Area C, Phase 1)**
  - EPRI funded investigation into Zry-2 vs. Zry-4 hydrogen pickup fraction change at high burnup (Why only accelerated in Zry-2?)
  - Transmission Electron Microscopy (TEM), Scanning TEM, Micro X-ray diffraction examinations planned – AREVA samples are already available

[ ]

AREVA is backing its commitment to the BWR market with active PIE and R&D efforts

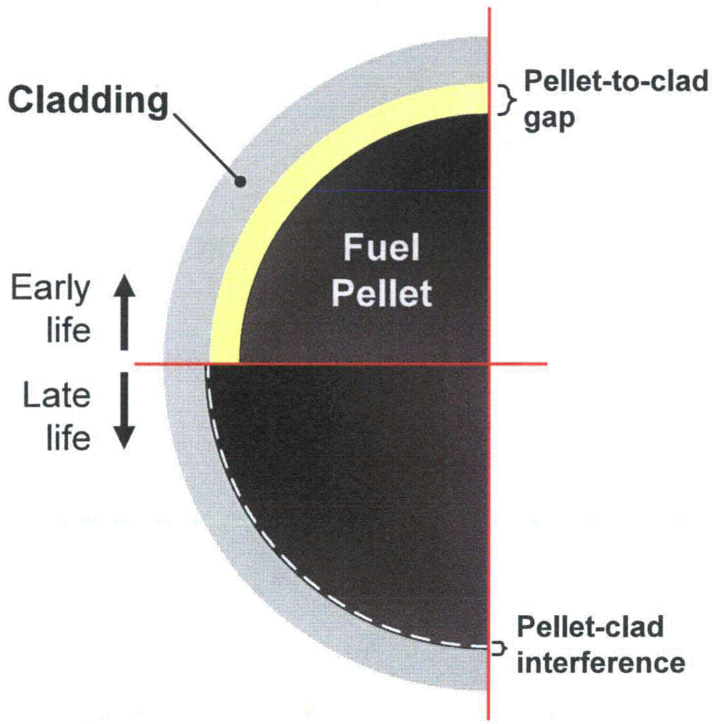
[ ]

Enhanced BWR Core Monitoring Approach for Reducing PCI Fuel Rod Failure Risk

AREVA has developed XEDOR™* to improve PCI management and enhance fuel reliability

[ ]

Accurate cladding stress calculations are rapidly executed with XEDOR™ algorithms



- XEDOR™ algorithms track changes in pellet and clad dimensions based on incremental power history
- Reduced order models are reverse engineered from AREVA's RODEX thermal-mechanical analysis code
  - Cladding creep characteristics
  - Pellet swelling and thermal expansion
- Interference vs. time is used to calculate peak cladding hoop stress

Fast execution allows use in online monitoring

AREVA is working with our reload customers to use XEDOR™ for improving operations

[ ]

AREVA NP Inc.

XEDOR™ supports risk-informed planning of sequence exchanges

[ ]

XEDOR™ has been specifically developed to enhance power maneuver management

- **Maintains real-time status of pellet-to-clad gap conditions as calculated at each monitoring system time step** (~ every 2 minutes)
  - **Inherently captures deconditioning effects of local low power operation for each 6" node of every fuel rod in the core**

[ ]

PWR Operating Experience

Anant Mohan
Supervisor, PWR Fuel Rod Design

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Topics

- M5® material Operating Experience (OE)
- US PWR Failure Summary
- 2010 Achievements, Fuel Examinations, and Observations
- 2011 Focus

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M5® Alloy on the PWR Market
(As of October 2010)

Components	*Plants*
M5® Clad Fuel Rods *(3,600,000)*	85
M5® Clad Fuel Assemblies *(14,700)*	85
M5® Clad Reloads *(340)*	71
M5® Clad and Guide Tubes *(7,200)*	42
All M5® Assemblies *(5,200)*	42

- Two main designs
  - AFA 3G™, HTP™
- Introduced in 1997 and now delivered in 13 different countries
- Six countries loaded more than 500 fuel assemblies
  - France
  - US
  - Germany
  - China
  - Belgium
  - Sweden

» ***M5® is the reference alloy for AREVA PWR fuel - in 2010, 66% of the PWR plants received M5® material***

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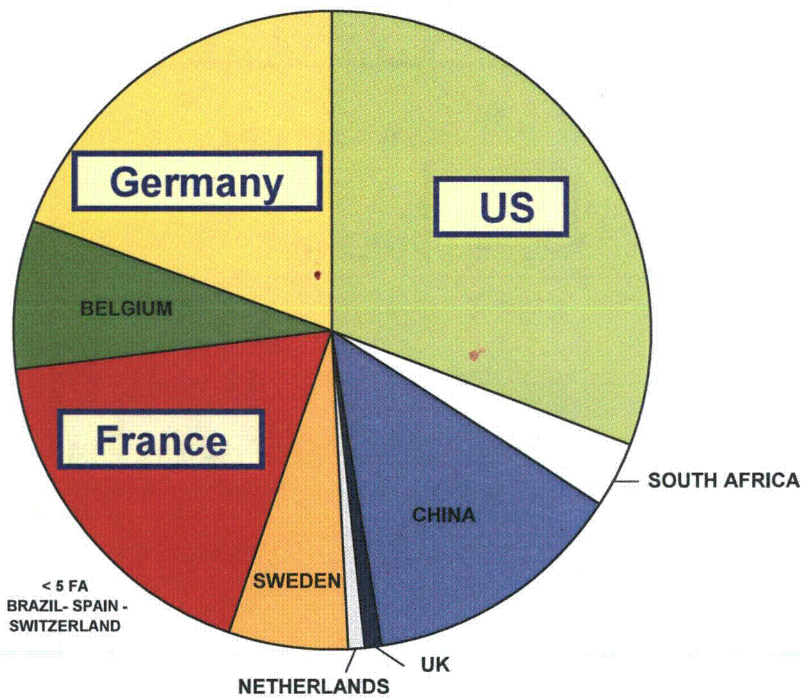
M5® Experience for Top 3 Markets

Fuel assemblies supplied per country



Country	Number of Reactors	T_{out} (°F)	Max fuel rod linear power integrated on a cycle (kW/ft)	Tested chemistry (Li content BOC - ppm)	Zn injection
Belgium	5	624	10.30	3.5	
Brazil	1	621	9.84	2.2	Yes
China	4	621	7.62	3.5	
France	30	624	7.25	2.2 & 3.5	
Germany	11	624	10.49	2	Yes
Netherlands	1	606	10.52	2.2	
South Africa	2	599	8.23	3.5	
Spain	1	619	6.74	3.5	
Sweden	3	617	9.91	5	
Switzerland	1	617	11.09	2.2	Yes
UK	1	617	7.53	2.2	
USA	16	622	7.04	3.5 to 5	Yes

M5® irradiation experience covers a wide range of demanding operating conditions

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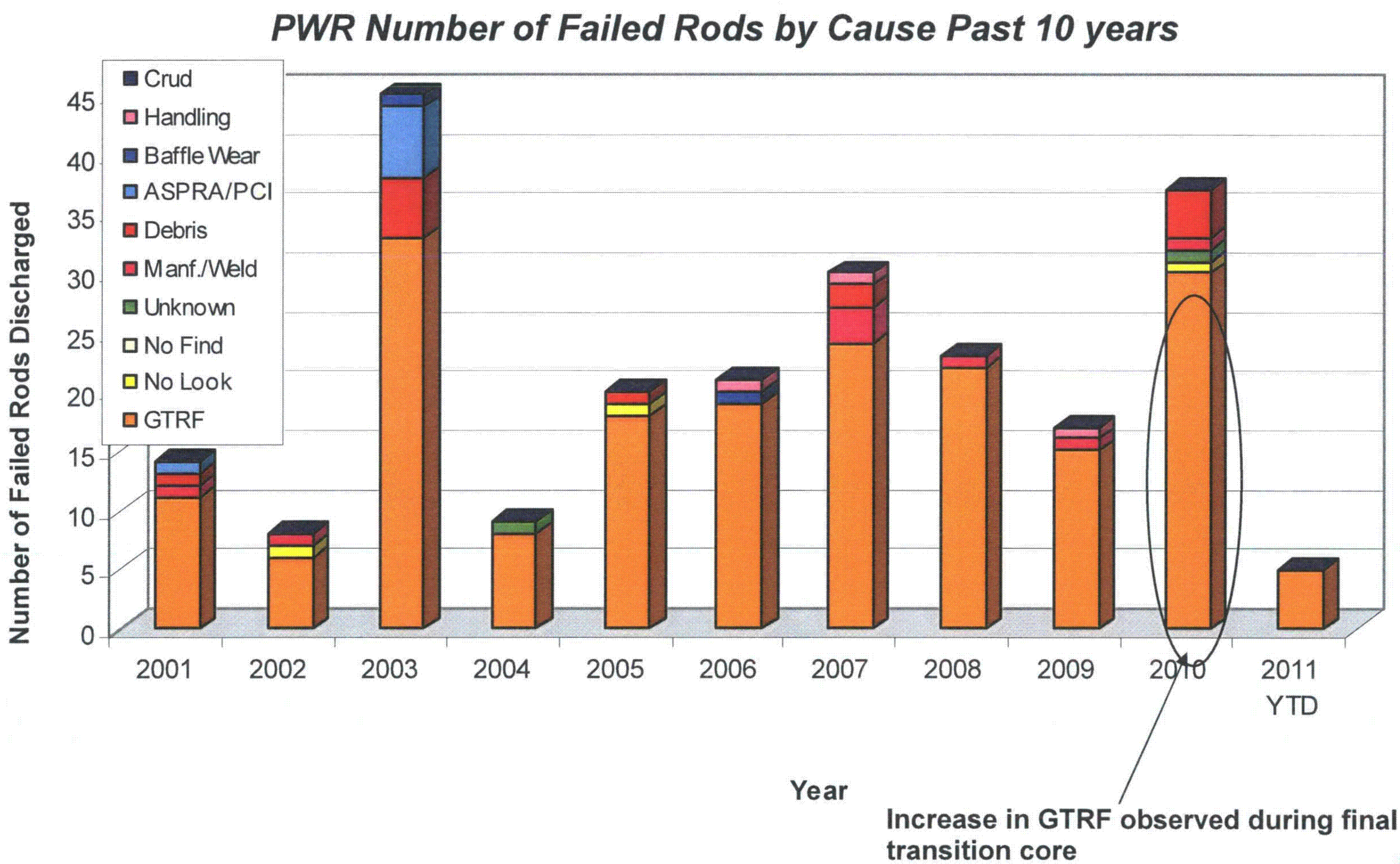
US PWR Failure Summary for the Last 10 Years



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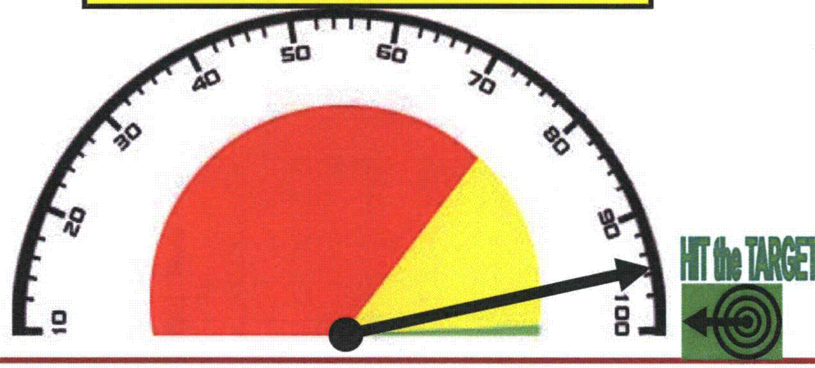
US PWR AREVA fueled cores → complete HTP™ transition and sustain

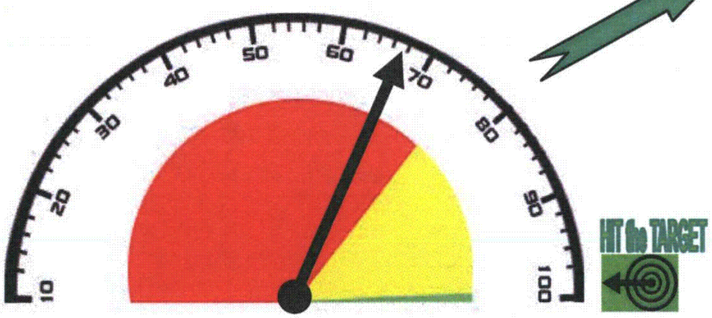
» Improvement in reliability as GTRF resistant HTP™ designs are implemented

17 out of 18 Customers

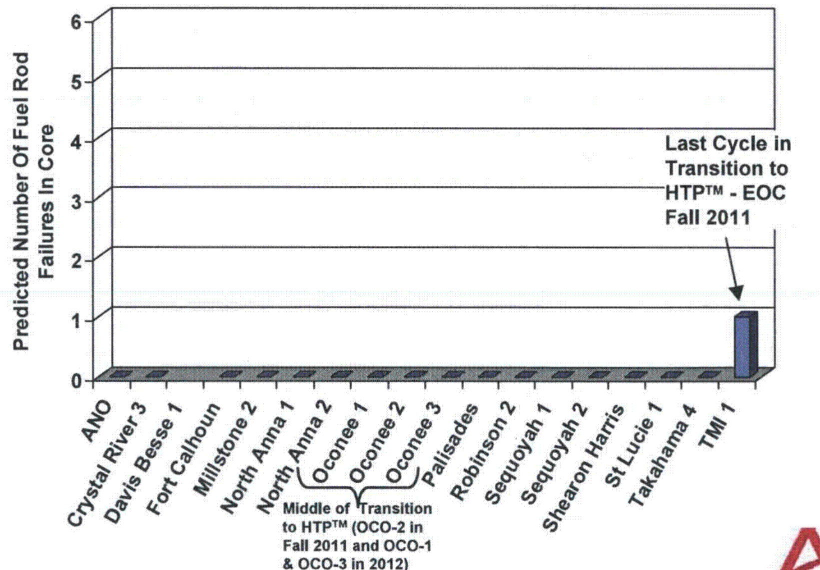


PWR Fuel Performance Status as of 05/24/11

12 out of 18 Customers



PWR Fuel Performance Status as of 10/13/08



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2010 Achievements from OE

- **Progress towards elimination of spacer grid fretting failures**
  - **Reactors having successfully completed the transition**
    - St Lucie 1 – bi-metallic to HTP™
    - Fort Calhoun – CE to HTP™
    - Crystal River 3 – Mark-B to Mark-B-HTP™ (completed 24 month cycle, No Failures)
    - ANO 1 – Mark-B to Mark-B-HTP™ (completed 18 month cycle, No Failures)
    - Davis-Besse – Mark-B to Mark-B-HTP™
    - Millstone 2 - HMP™ bottom grid
  - **Reactors in transition**
    - TMI 1 – Mark-B to Mark-B-HTP™, complete 2011
    - Oconee 1, 2, & 3 – Mark-B11 to HTP™, complete 2012
    - Sequoyah- transition to begin in the fall 2012 on Unit 2

» ***HTP is effective in eliminating GTRF failures***

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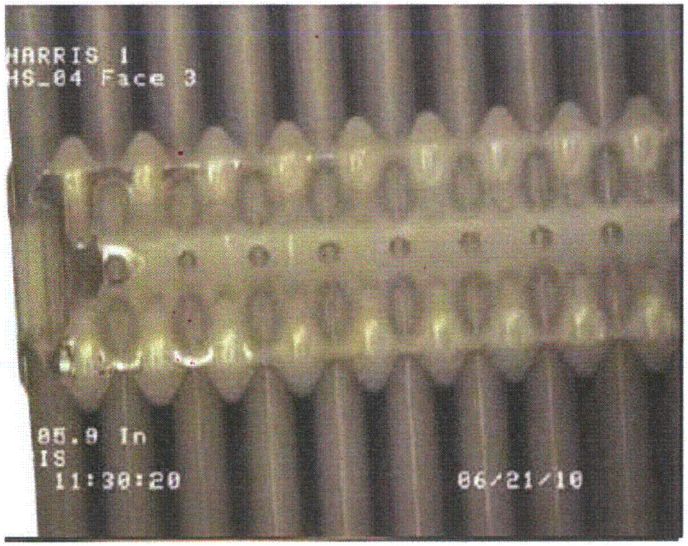
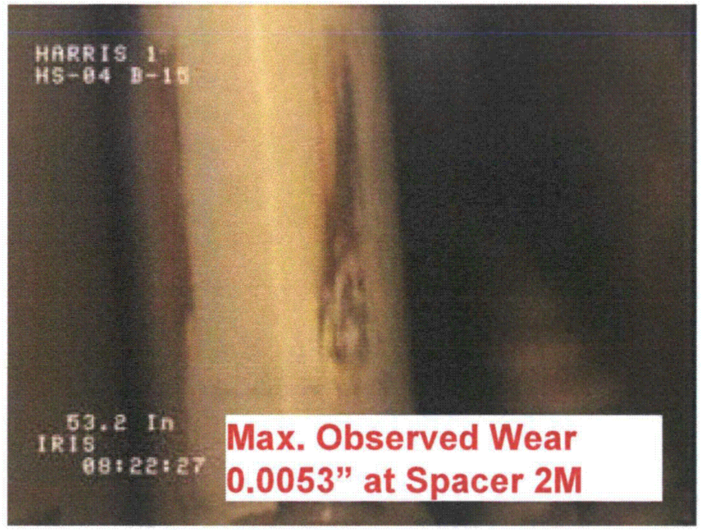
Baseline Fuel Inspection Results
Grid-to-Rod Fretting

[ ]

- Three assemblies (3rd-burn, discharged), core periphery
- 58 total rods
- Range of wear depth: 0 to [ ]





» Maximum Fuel Rod Wear In Presence of Minor Grid Wear – Large Structural Margin Exists

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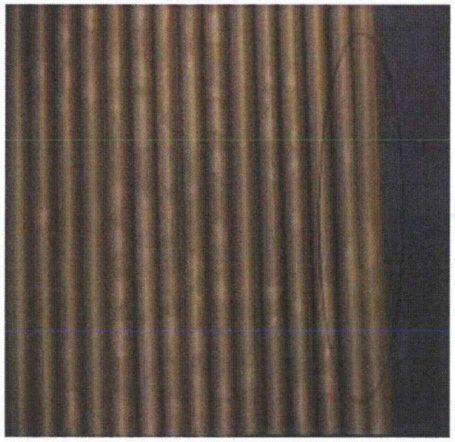
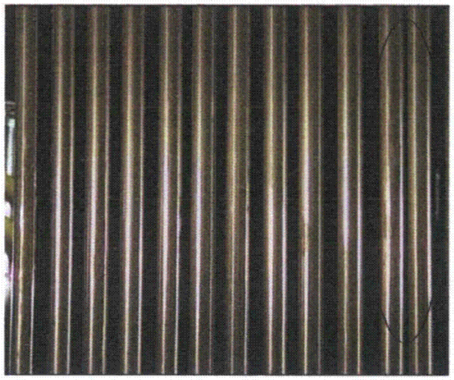
PWR Fuel Rod Bow Observations

- **Current Situation**
  - Adv. Mark-BW (N. Anna-1 & 2) exhibited significant bow - 19 assemblies with bow to closure or envelope or envelope violations – design w/o upper end grid improvements.
  - Mark-BW (Seq-2 RFO17) exhibited isolated occurrences of significant bow with no gap closure.
- **What have we learned?**
  - Issue is still isolated to the Mark-BW design
  - Mark-B HTP™ and CE-14 HTP™ design – data indicate no concern
- **Future Plans**
  - Perform additional PIE inspections – monitor.

North Anna-1 2010



Sequoyah-2 2011



» Mark-BW is being phased out

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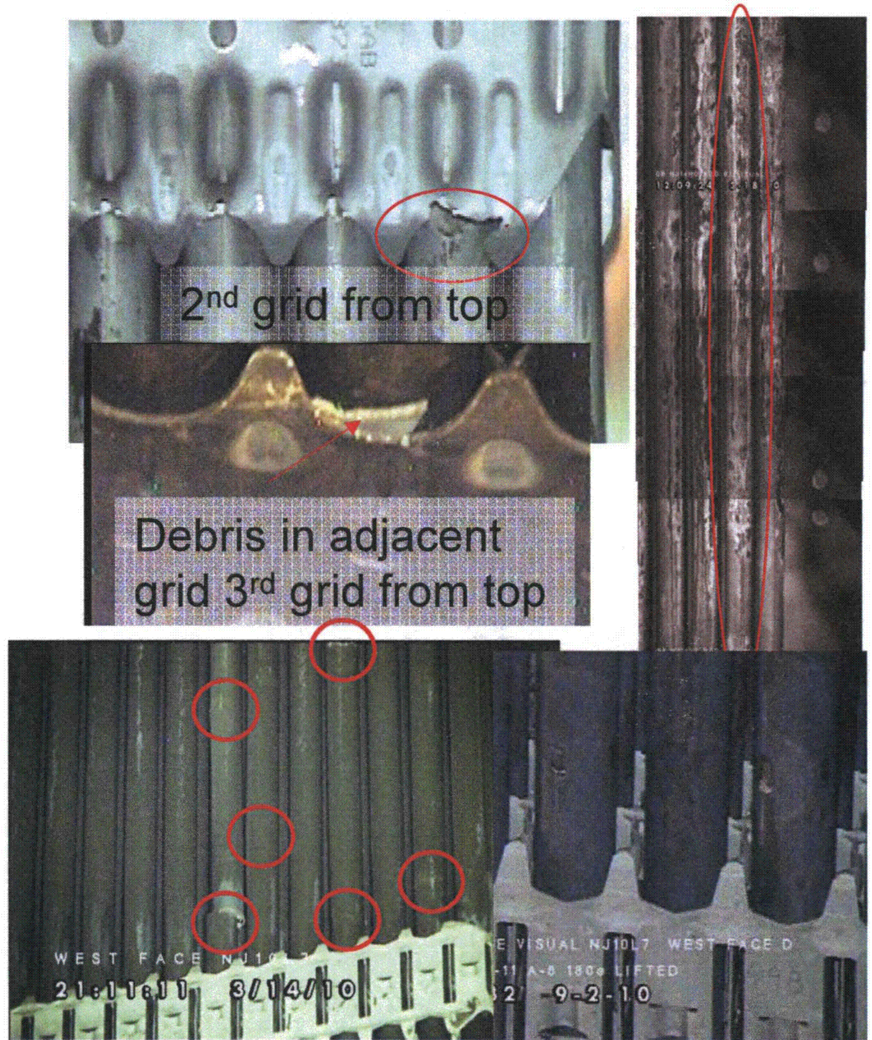
2010/2011 Cause of Failure Examinations

Davis-Besse EOC 16

- NJ14HD
  - Additional Cause of Failure Exams were performed on NJ14HD rod B1.
  - NJ14HD was originally believed to be a CILC failure, but after additional inspections is now believed to be a debris failure.
- NJ10L7
  - 3rd cycle baffle assembly with 6 rods in a row failed on face opposite the baffle with no signs of handling damage or debris fretting
  - Side rod lifts and visuals confirmed GTRF as failure mechanism
  - A total of 8 rods were visually verified as failed within this assembly
- Four third cycle assemblies were found to have 8 additional failed rods due to GTRF



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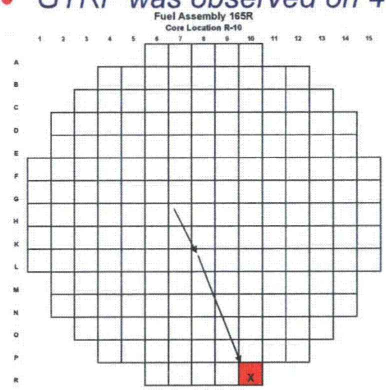
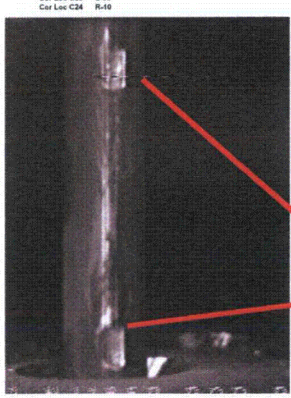
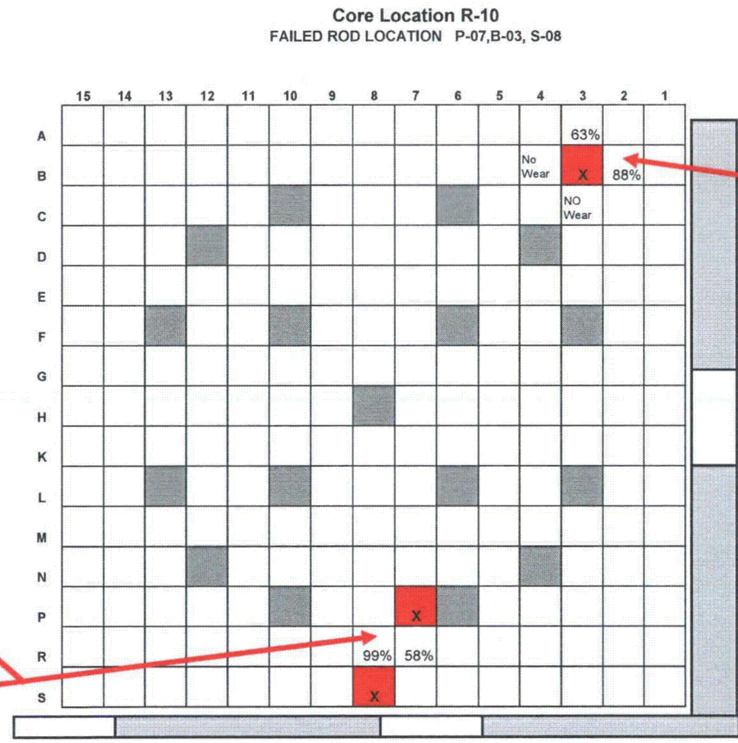
2010/2011 Cause of Failure Examinations (Continued)

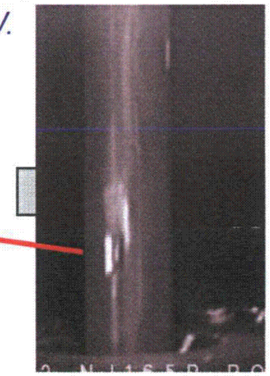
Oconee 2 EOC 24

- ***5 Fuel Assemblies – 3rd cycle - containing a total of 8 failed rods***
  - *GTRF was verified to be the cause of failure for all 8 rods*
- ***Additional rods were pulled from NJ165R to check for interior rod GTRF***
  - *GTRF was observed on 4 of the 6 rods pulled. Severity ranged from 58% to 99% TW.*









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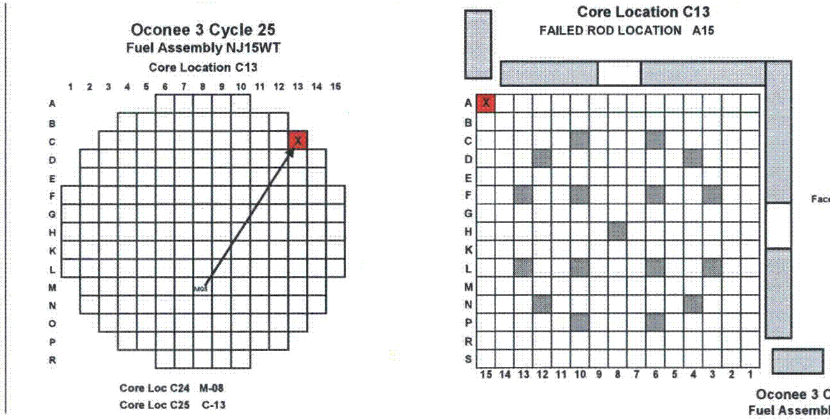
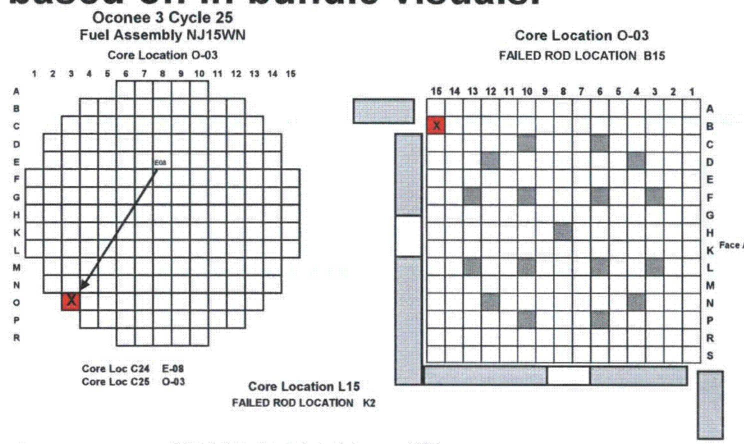
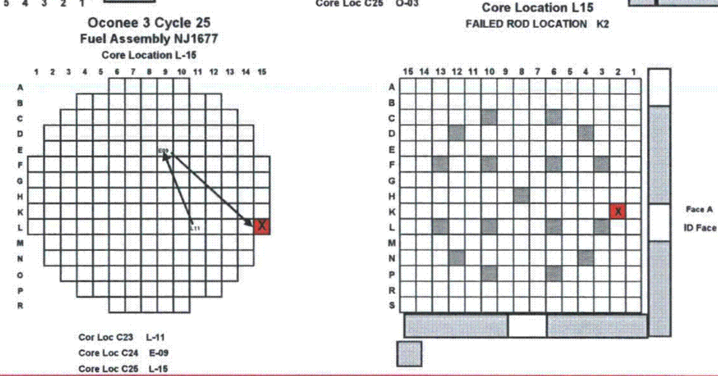
2010/2011 Cause of Failure Examinations (Continued)

- **Oconee 3 EOC 25**
  - **Three assemblies from baffle locations were failed.**
  - **The rods in all 3 were in historical GTRF locations in front of either a slot or LOCA hole location.**
  - **All three are assumed to be GTRF based on in bundle visuals.**







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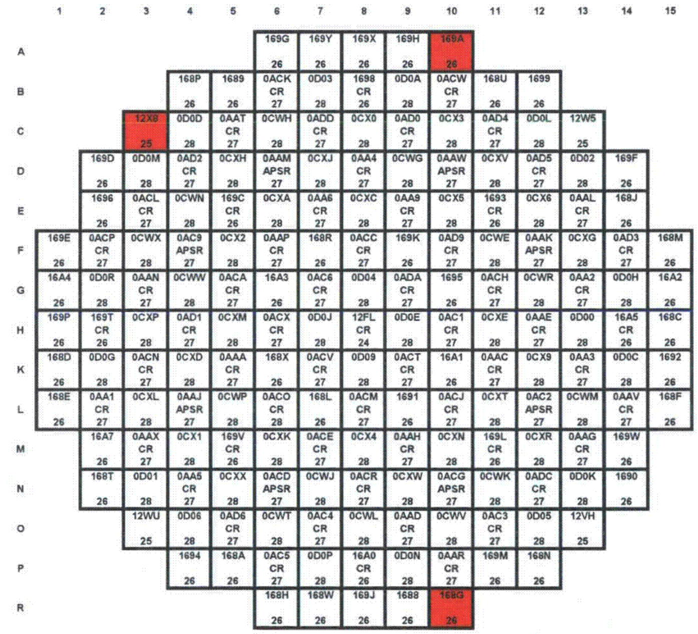
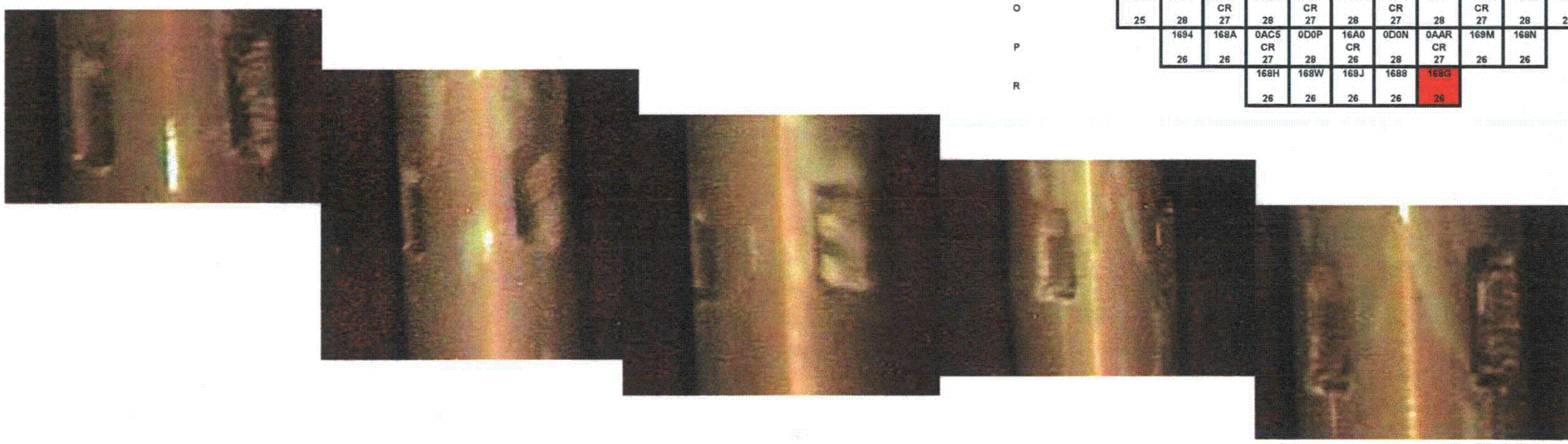
2010/2011 Cause of Failure Examinations (Continued)

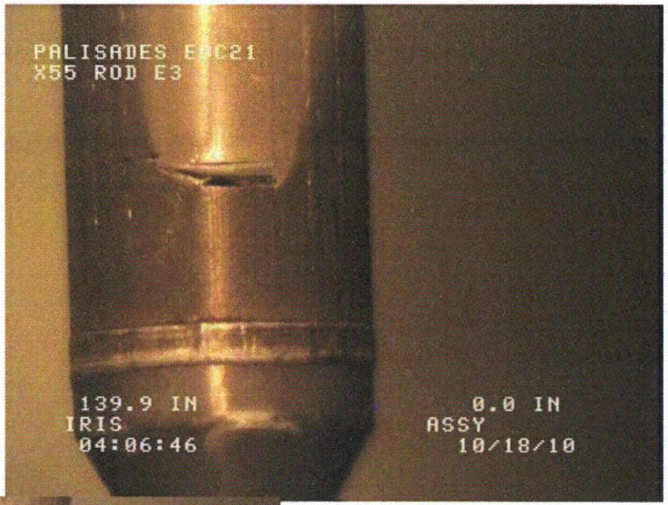
- **Oconee Unit 1 EOC 26**
  - 3 MK-B11 fuel assemblies were confirmed failed due to GTRF.
  - All 3 were in core locations which had historically had GTRF failures (2 were in LOCA hole locations and 1 was in a double slot location
  - The failures were verified both with UT and visually





2010/2011 Cause of Failure Examinations (Continued)

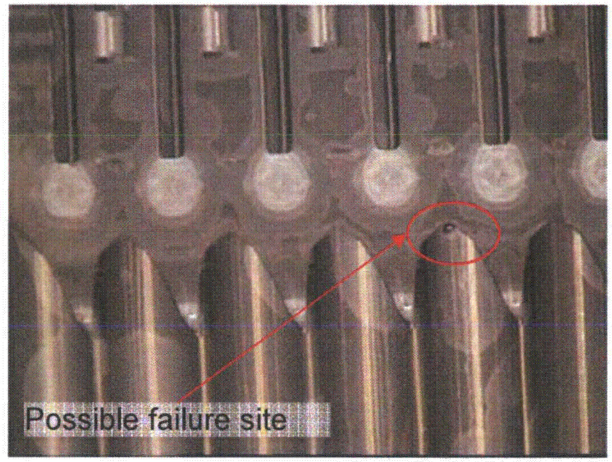
- **Palisades EOC 21**
  - **X24 and X55 were identified as failed by sipping**
  - **Assembly X55 rod E3 (interior) was removed and a debris scar was visually identified and confirmed with eddy current.**
  - **Assembly X24 rod A15 (periphery) span 3 from the bottom a debris scar was visually identified and confirmed with eddy current.**



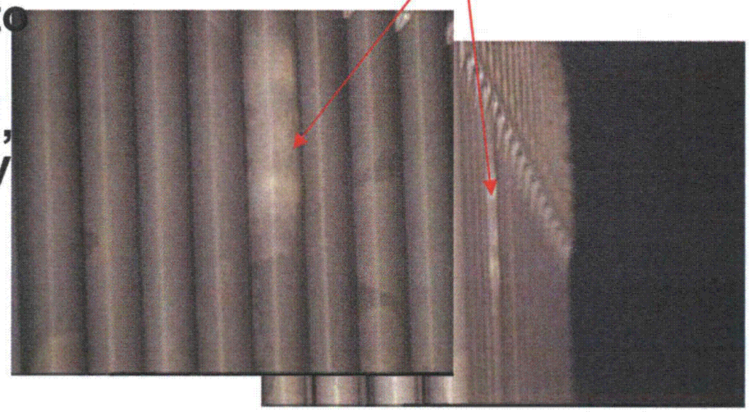
2010/2011 Cause of Failure Examinations (Continued)

North Anna 1 EOC 21

- 03B was 2nd cycle baffle assembly
  - Failure occurred approximately 7 months into cycle
  - Core location did not have a history of GTRF
  - Hydride on rod A5 below the 2nd grid from the top
  - Rod could not be removed due to the rod being separated
  - No primary failure site identified, but most likely debris or primary hydride

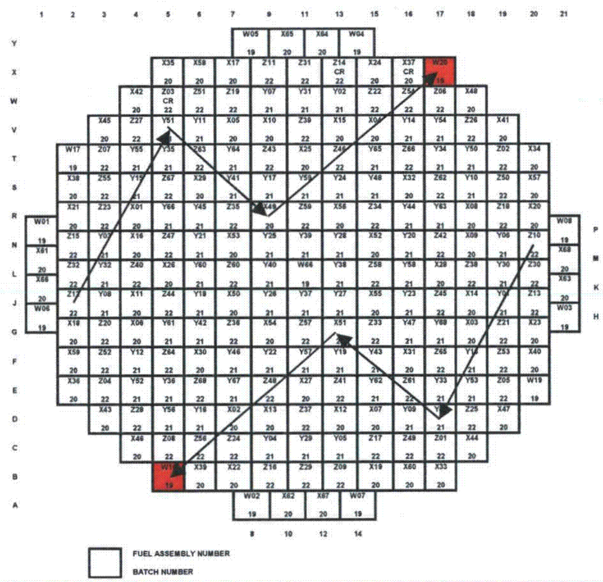


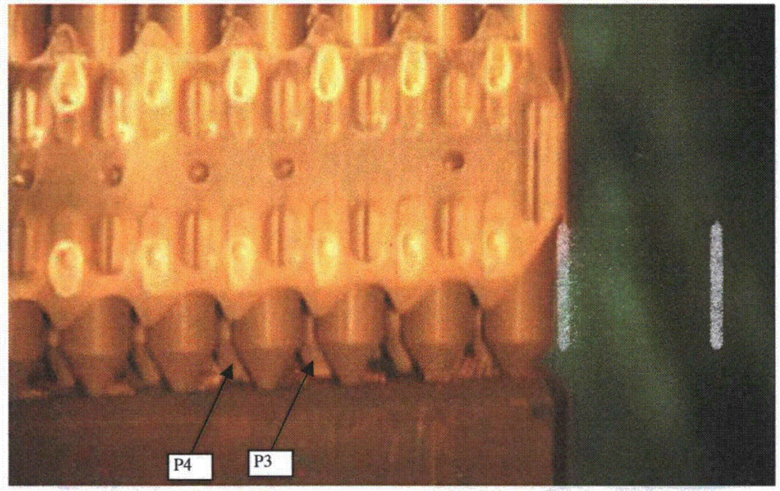
Hydride Blister Below Grid 2

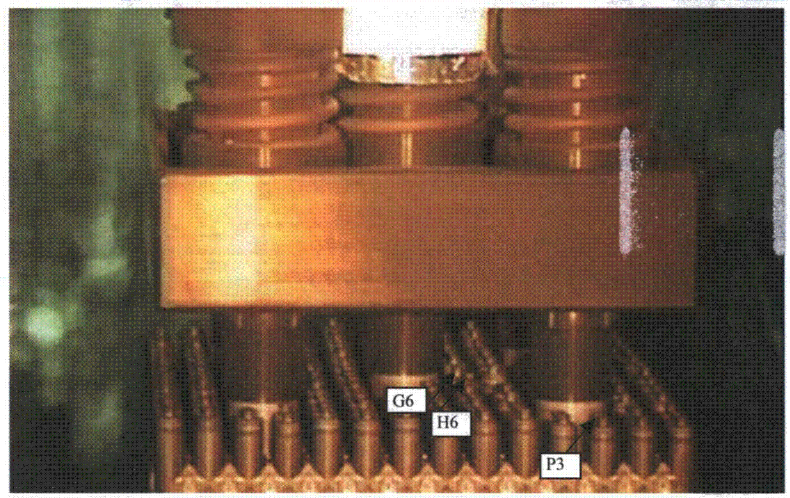


2010/2011 Cause of Failure Examinations (Continued)

- **Millstone Unit 2 EOC 20**
  - 2 fourth cycle CE14 assemblies (with no lower HMP) were identified as failed by sipping
  - Both assemblies were in core locations where spinning rods had occurred
  - Both assemblies had loose rods and lower end plug wear







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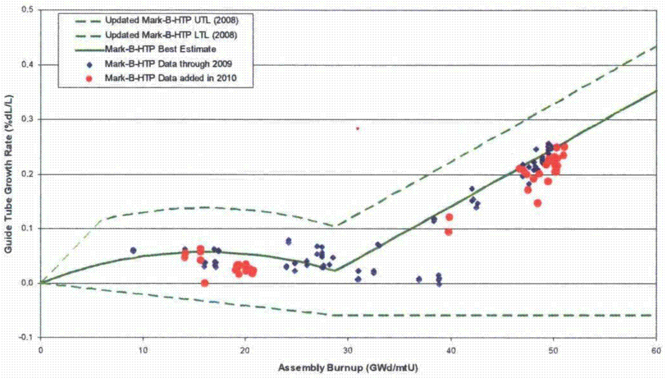
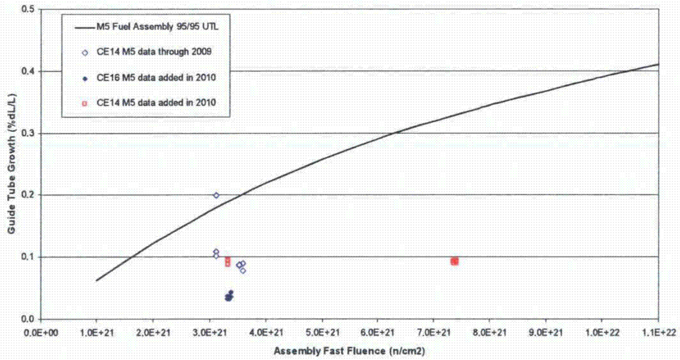
PWR M5 Fuel Assembly Growth

- **Current Situation**
  - **Growth laws revised**
  - **Fuel assembly lengths adjusted where necessary**
  - **Data gathered in 2010 are within design limits**
- **Future Plans**
  - **Continue to monitor growth**
  - **Use data to improve predictive models**

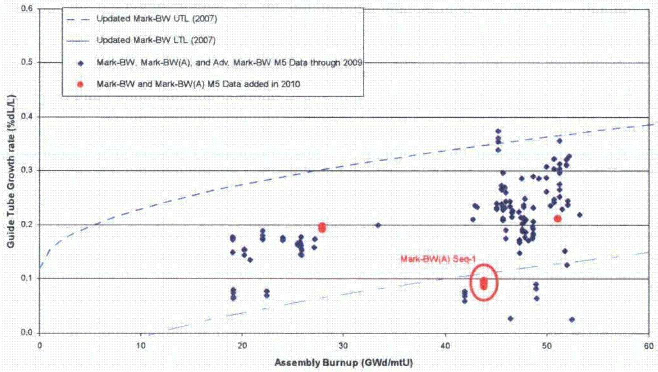
MK-B-HTP M5



CE M5



MK-BW M5



» ***Data has supported new growth laws and reinforced assembly length change***

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2011 Focus - PWR Crud

▶ Current Situation

- ◇ **Heavy Crud deposits have been observed at CR3, D-B, and TMI-1**
  - At D-B 2 rods were observed to have E/C evidence of wall thinning (maximum of 23%)
- ◇ **Ultrasonic Fuel Cleaning was employed at both CR3 and D-B to reduce the impact of the Crud inventory on future cycles.**
- ◇ **No unusual Crud has been observed anywhere else.**

▶ What have we learned?

- ◇ **Elevated Crud Root Causes Analysis complete – Combination of three factors –**
  - Higher hydraulic resistance of the Mark-B-HTP grid compared to the Mark-BZ grid which, in a mixed core leads to flow diversion away from HTP locations resulting in elevated temperatures and higher steaming
  - High corrosion release rates from alloy-600 steam generator material
  - Insufficient crud removal by RCS cleanup practices
- ◇ **Emphasis placed on improving Crud prediction (Level I, II, III, and IV risk assessments) for core design input and cleaning recommendations**

▶ Future Plans

- ◇ **Perform risk assessment using Level III and IV tools – Establish adequate benchmarks and establish CIPS and CILC criteria**

» ***Goal is to maintain a Crud Safe Environment***

Summary

- HTP™ continues to demonstrate successful performance against grid-to-rod fretting
- AREVA is making progress towards elimination of grid-to-rod fretting failures by transitioning to HTP fuel in the US
- No new performance issues revealed through cause of failure examinations performed in 2010
- M5 fuel assembly growth data collected in 2010 support growth laws
- Elevated Crud Root Cause Analysis complete. Emphasis placed on improving Crud predictions

» ***The Goal To Eliminate Leaking Fuel Is In Sight And AREVA Has A Plan To Get There!***

PWR Fuel Exams

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Topics

- PWR Program Objectives
- Test Assembly Programs
- 2010 Poolside PIEs
- M5® Experience Summary
- Zircaloy-4 Experience Summary

PWR Exam Objectives

- Purpose of the latest PIE data is to specifically support the following fuel designs:
  - Mark-B (15x15, B & W Reactor)
  - Mark-BW (17x17, W Reactor)
  - W-HTP (15x15, 17x17, W Reactor)
  - CE-HTP (14x14, 15x15, 16x16, CE Reactor)

Comprehensive plan developed by product design

PWR Test Assembly Programs

PWR Test Assembly Programs
(Continued)

PWR Test Assembly Programs
(Continued)

PWR Test Assembly Programs
(Continued)

[ ]

Well defined LTA program for advanced products

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2010 Poolside PIEs

[ ]

2010 Poolside PIEs
(Continued)

[ ]

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2010 Poolside PIEs
(Continued)

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2010 Poolside PIEs
(Continued)

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2010 Poolside PIEs
(Continued)

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2010 Poolside PIEs
(Continued)

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2010 Poolside PIEs
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2010 Poolside PIEs
(Continued)

M5 Experience Summary

M5 Experience Summary
(continued)

M5 Experience Summary
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M5 Experience Summary
(continued)

M5 Experience Summary
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M5 Experience Summary
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M5 Experience Summary
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M5 Experience Summary
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Zircaloy-4 Experience Summary

Zircaloy-4 Experience Summary
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Zircaloy-4 Experience Summary
(continued)

Zircaloy-4 Experience Summary
(continued)

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Cruciform Spring Update

Tom Gardner
Fuel Mechanics

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Mark-B Holddown Springs – Background Summary

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Mark-B Holddown Springs – Background Summary

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Mark-B Holddown Springs – Background Summary

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Mark-B Holddown Springs – Background Summary

▶ Immediate Response

◇Performed Operability Assessments for Fuel In Core

◇Initiated Inspections at the Plants in an Outage (TMI & OCO)

◈Developed Recovery Plan for Impacted Sites

Operation Status

- **All Suspect Springs were Removed from Service**
  - Upper End Fittings replaced on all re-insert Mark-B-HTP fuel assemblies
  - Mark-B11 fuel assembly spring performance being monitored (Oconee)

- **Inspections Underway on New Springs**
  - Inspections are planned for first three operating cycles for new springs
  - Spring preload/spring rate and visuals

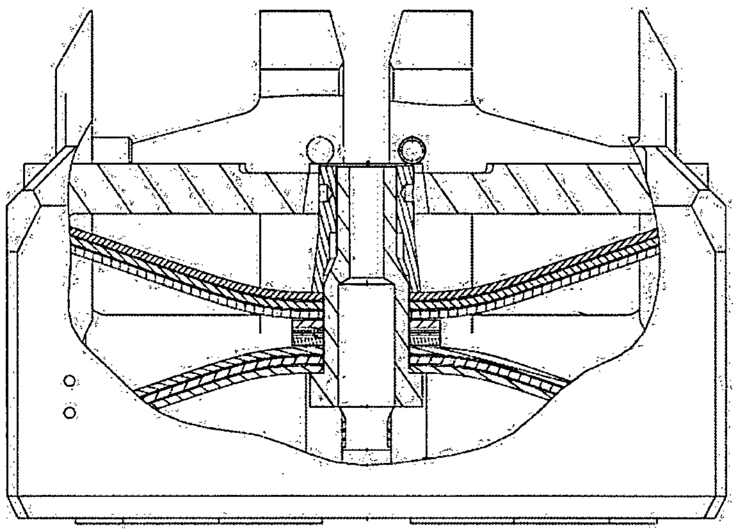
- **Fuel Assembly Burn-up Limit Withdrawn**
  - Damage on springs below limit

Inspection Status

Inspection Status

▶ Next Inspections (tentative)

- ◇ ANO-1 – Fall 2011
- ◇ TMI – Fall 2011
- ◇ Davis-Besse – Spring 2012



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Status of SCC Testing

Status of SCC Testing

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Status of Proposed Hot Cell Examination

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Status of Root Cause Investigation

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PWR Crud Risk Management Tools (Thermal-Hydraulics)

Richard Harne
Advisory Engineer – PWR Thermal Hydraulics

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Agenda

Current Status of Crud in AREVA PWR Fueled Cores

Status of AREVA's PWR Crud Risk Assessment Tools

On-going Development and Applications

Current Status of Crud in AREVA PWR Fueled Cores

- B&W 177FA Plants

Crud Root Cause Analysis

- Condition Reports (WebCAP) had been written regarding the observed severity of crud deposition at [several B&W 177FA Plants.]

- A Root Cause Analysis Team was formed and examined the condition

- The root cause was identified as a combination of three factors:

[ ]

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Summary of Crud Observations

Proactive measures have been taken reduce the CIPS and CILC risks.

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Crud Status in B&W 177FA Plants

[ ]

Proactive measures taken to arrest the crud condition have included ultrasonic fuel cleaning (UFC)

Agenda

Current Status of Crud in AREVA PWR Fueled Cores

Status of AREVA's PWR Crud Risk Assessment Tools

On-going Development and Applications

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AREVA PWR Crud Risk Evaluation Methods

Five Levels of PWR Risk Assessments (corresponding to EPRI's Four Levels plus a 2.5 Level):

- **Level 1,** Review of changes to determine if within operating experience
- **Level 2,** Three-dimensional core steaming rate analysis (with LYNXT) using fuel assembly quadrant resolution
- **Level 2.5,** Like Level 2 but with "enhanced evaluation methods"

[ ]

- **Level 3,** Three-dimensional core steaming rate analysis (with COBRA-FLX) with subsequent PWR FDIC code (Fuel Deposition Interactive Chemistry) evaluation
- **Level 4,** Computational Fluid Dynamics (CFD) with PWR FDIC

AREVA PWR Crud Risk Evaluation Methods

Enhanced Evaluation Techniques Introduced with Level 2.5

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Enhanced Evaluation Techniques Introduced with Level 2.5

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Enhanced Evaluation Techniques Introduced with Level 2.5

- Fuel assembly quadrant steaming rates are computed and the limiting assemblies are tracked

Level 3 Enhancements for COBRA-FLX Local Subchannel Conditions

- **High resolution capability**
  - **COBRA-FLX allows for full-core subchannel-by-subchannel resolution**
    - Allows for ability to predict most CILC conditions in the subchannel code without having to resort to finer CFD calculations
    - Allows for modeling all core regions in single calculation
  - **Highest fidelity achieved after benchmarking against CFD models and measured data**

[ ]

  - **Allows for generation of detailed boundary conditions to be used in the development of local CFD models**

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Level 3 Enhancements for COBRA-FLX Local Subchannel Conditions

- **Steaming Rate calculation basis**

[ ]

- **Extended visualization tools**
  - COBRA-FLX includes 3D imaging tools which provide greater capability to view and evaluate core conditions

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Level 3 Crud Risk Assessments

[ ]

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Level 3 COBRA-FLX and FDIC Benchmarking to Clad Wall Thinning Measurements

Level 3 COBRA-FLX Core Modeling

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Level 3 COBRA-FLX Core-wide Output Visualization Examples

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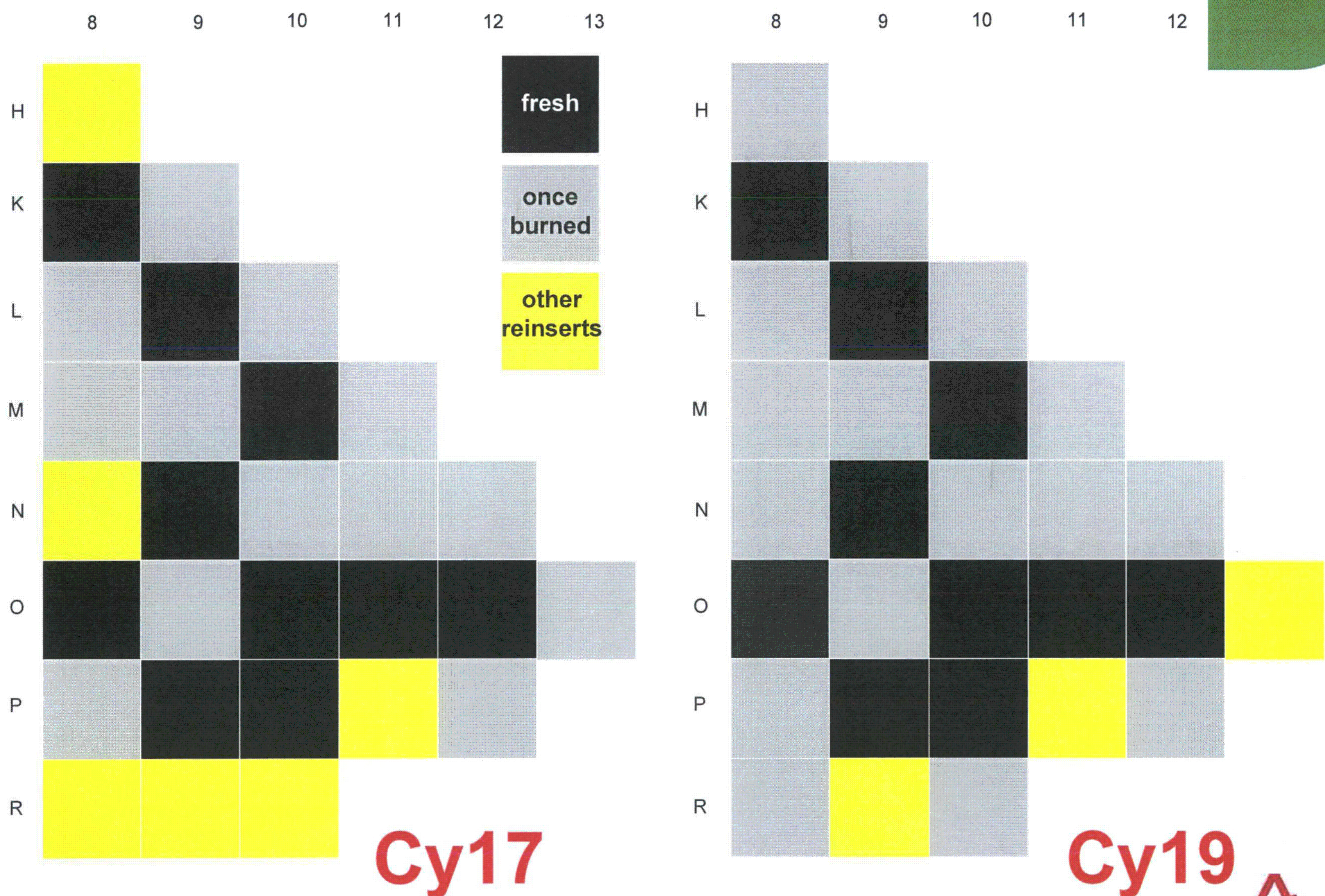
Core Configurations



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Bulk Coolant Temperature

Bulk Coolant Temperature

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Bulk Coolant Temperature

Bulk Coolant Temperature

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Bulk Coolant Temperature

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Bulk Coolant Temperature

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Bulk Coolant Temperature

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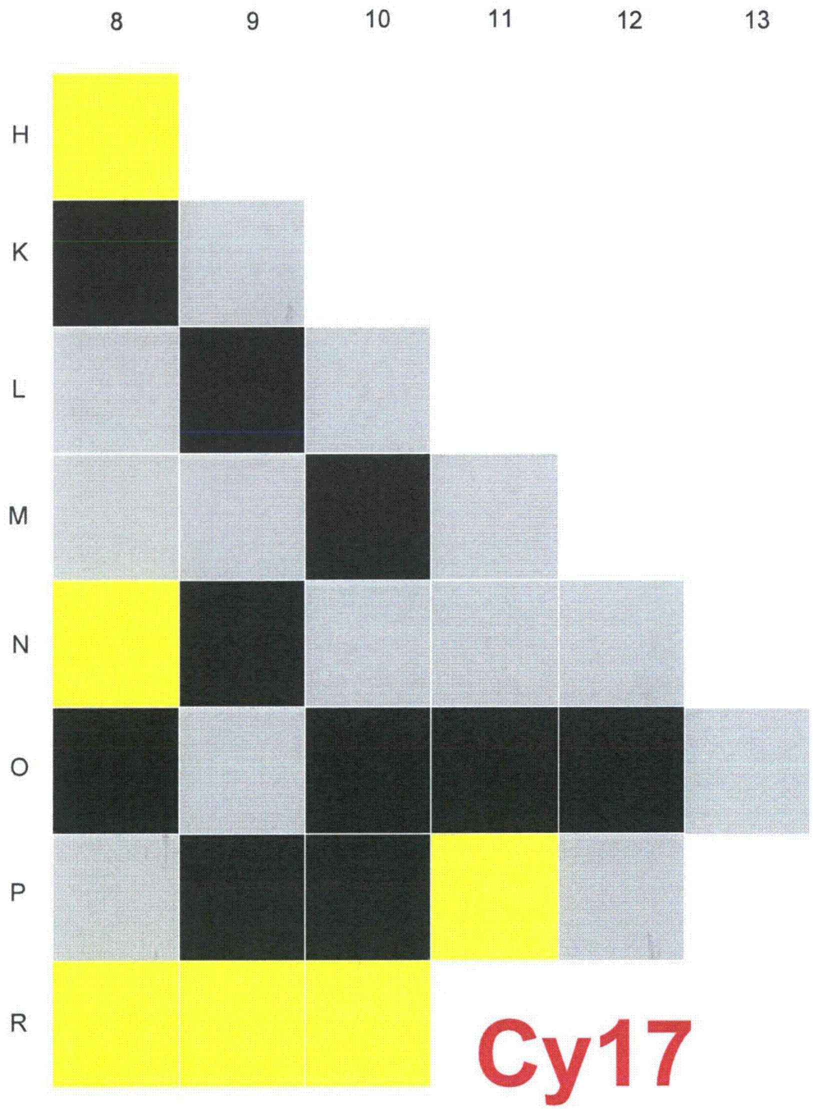
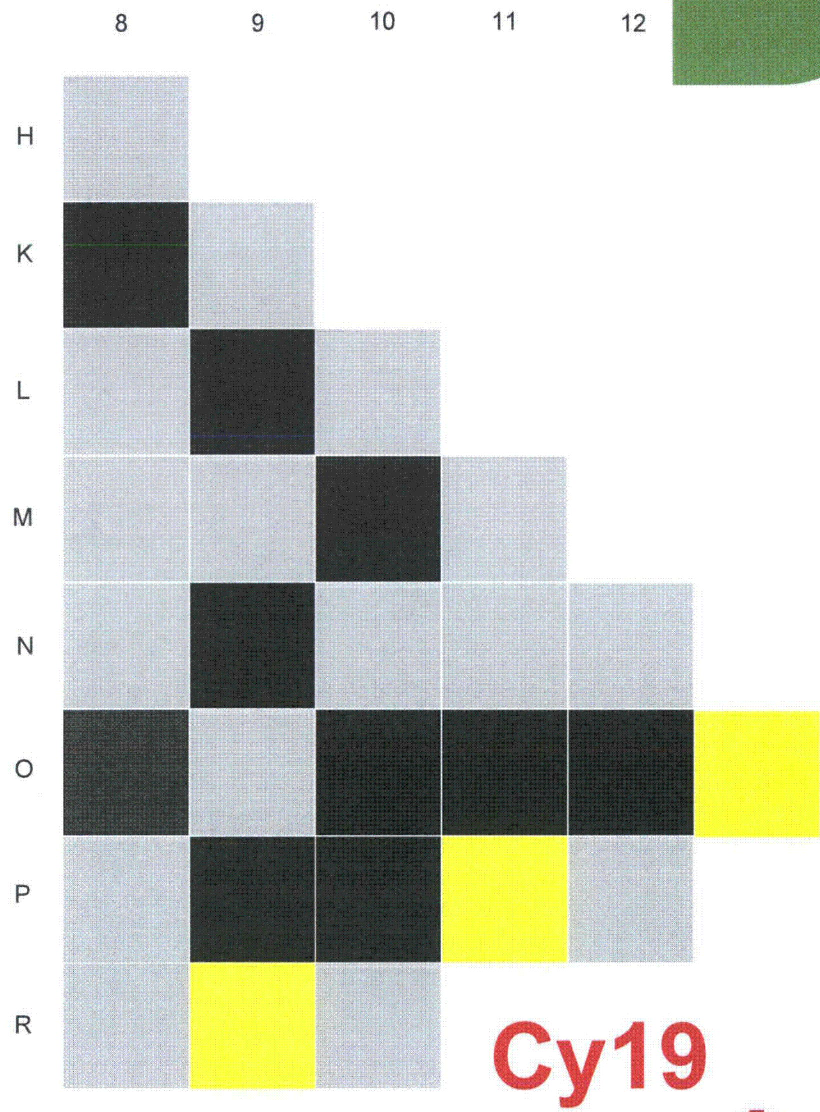
Bulk Coolant Temperature

Core Configurations





Cladding Surface Temperature

AREVA

Cladding Surface Temperature

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Cladding Surface Temperature

Cladding Surface Temperature

Cladding Surface Temperature

Cladding Surface Temperature

Cladding Surface Temperature

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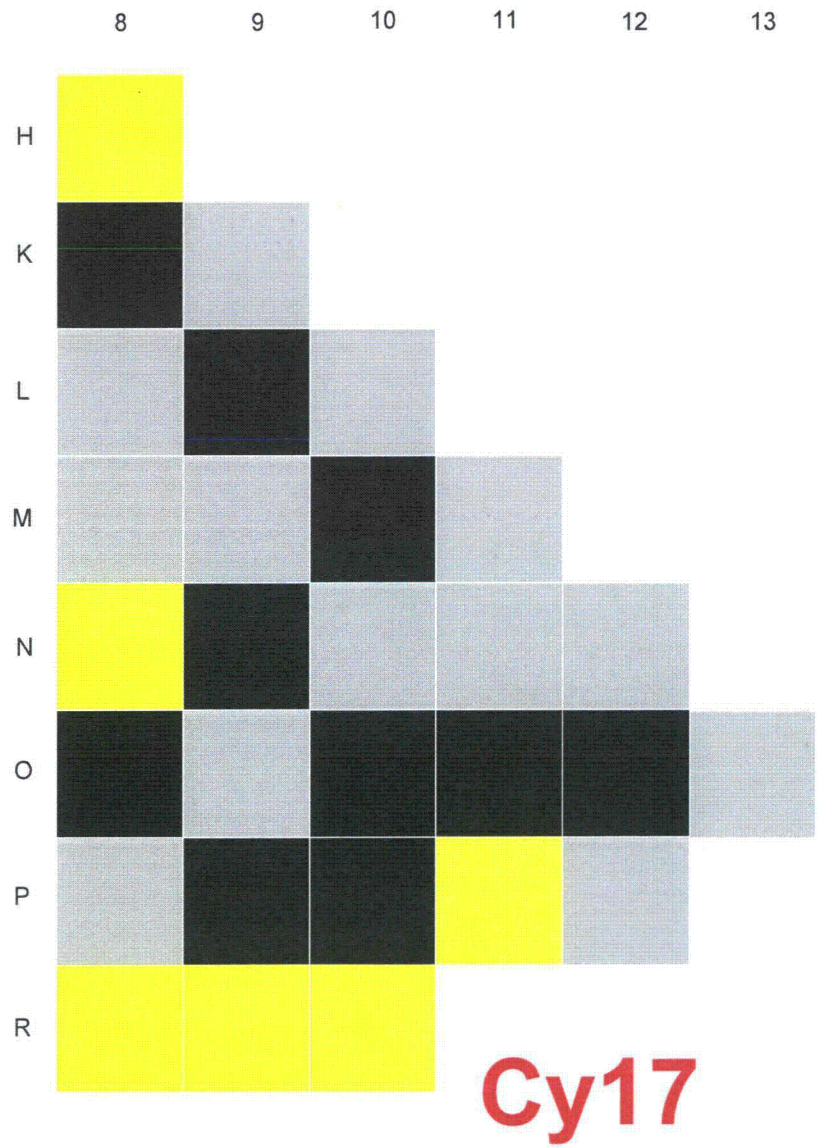
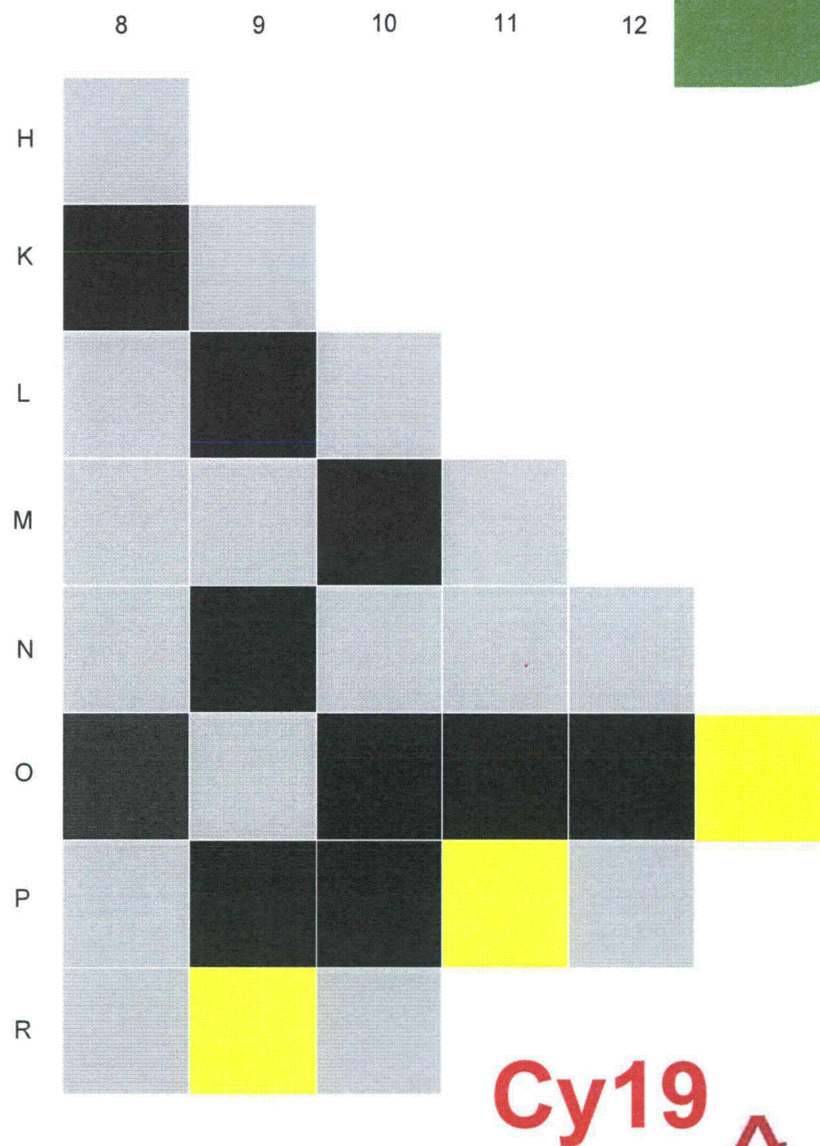
Cladding Surface Temperature

Core Configurations





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Steaming Rate

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Additional 3D Visualization Available Using AREVA's CoreView

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Additional 3D Visualization Available Using AREVA's CoreView

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AREVA Evaluation Method Applications to Plants with DCP Crud Conditions

Level 4 Crud Risk Assessment Tools

Level 4 Crud Risk Assessment Tools

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Level 4 Azimuthal Power Peaking Example

Level 4 Boundary Condition Interface between COBRA-FLX and CFD

Examples of high resolution and CFD interface

Level 4 COBRA-FLX Boundary Conditions for CFD

- Typical COBRA-FLX to CFD Boundary Conditions (Axial and Crossflow Velocities)

Level 4 CFD Predictive Results Example

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Agenda

Current Status of Crud in AREVA PWR Fueled Cores

Status of AREVA's PWR Crud Risk Assessment Tools

On-going Development and Applications

On-going Development Benchmarking

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Benchmarking for Level 3 and 4 Methods

Applications