Robust Fuel Program

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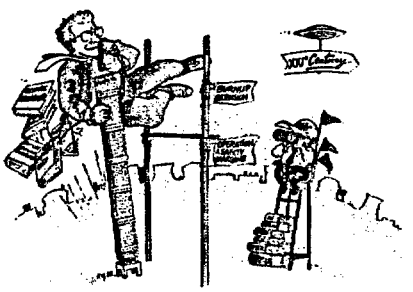
Utilities Formed The Robust Fuel Program In 1998

- Today's demanding operating conditions have reduced operating margins
- Competitive environment lessens ability to fund R & D to ensure fuel performs "as advertised"
- RFP is aimed at ensuring
  - Optimal fuel performance; avoiding operational surprises
  - Regulatory stability
  - Operating flexibility
  - Burnup extension



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ATTACHMENT 2

More Demanding Environment

- Increasing discharge burnups and long cycle length
- Increased fuel peaking and enrichment
- Plant uprates
- New water chemistry environments
  - Elevated pH/lithium and Zn injection for PWRs
  - NMCA, hydrogen water chemistry and Zn injection for BWRs
- Fuel design changes and introduction of new materials

Reduced margins and increased unknowns

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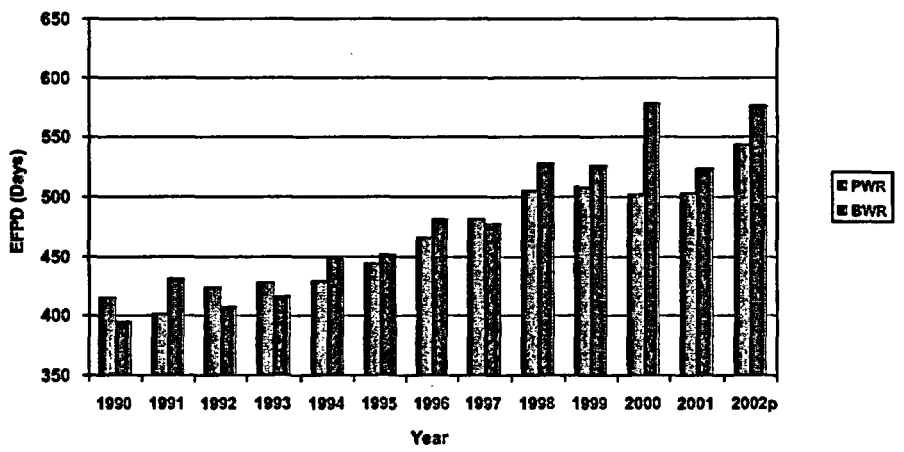
Trends In Cycle Length -U.S.



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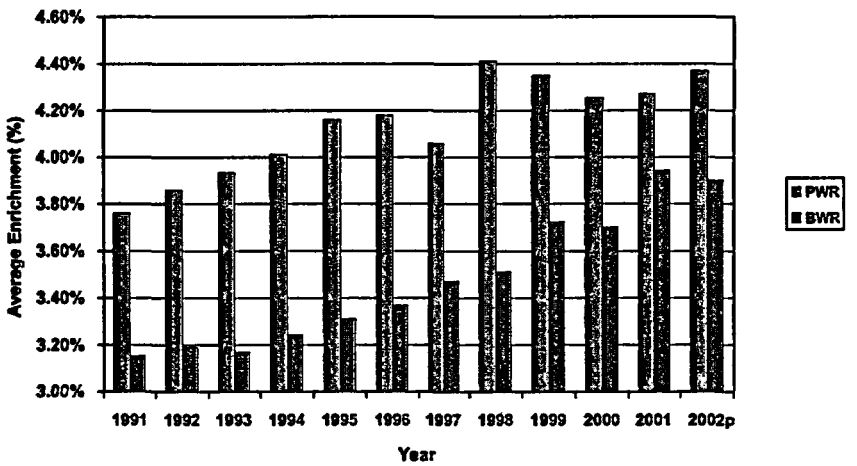
Trends In Average Initial Enrichment -U.S.



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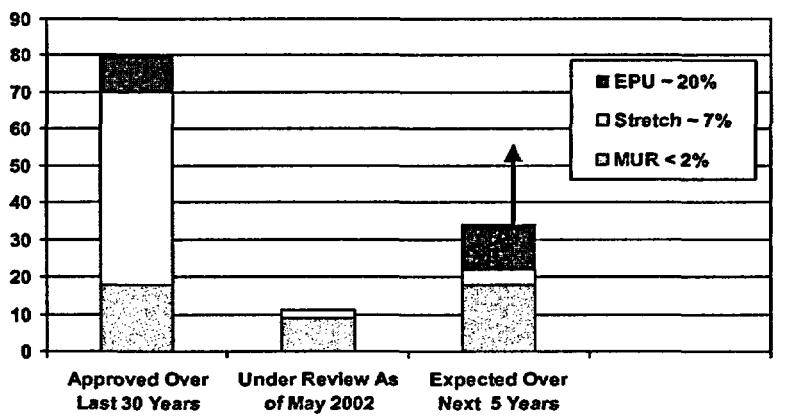
Number Of Uprated Applications In U.S.



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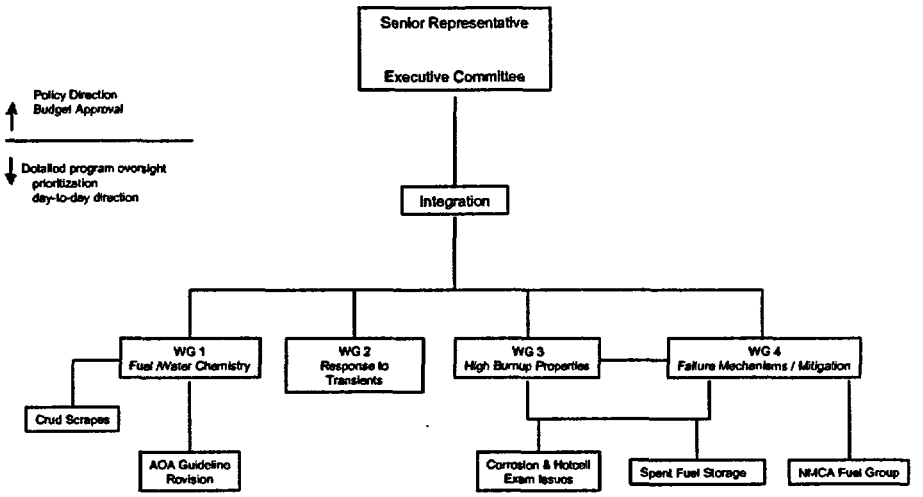
Robust Fuel Program Utility Steering Committee



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Executive Committee Members

Lyle Bohn, Nuclear Management Company
Ken Canady, Duke Energy
Bill Eaton, Entergy
Lou Long, Southern Nuclear
Jim Malone, Exelon Corp
Joe Sheppard, South Texas Project (Chairman)
Ausaf Husain, Fuelco

Gary Fader, INPO
Alex Marion, NEI

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Chairmen/Vice-Chairmen & Project Managers

	Chairman	Vice Chairman	Project Manager
Working Group 1	Dan Bryant (South Texas)	Kenny Epperson (Duke Power)	Jeff Deshon
Working Group 2	Nicolas Waeckel (EdF)	Bob Tsai (Exelon)	Odelli Ozer
Working Group 3	Dave Hoppes (South Texas)		Kurt Edsinger
Working Group 4	Bruce Hunt (Southern Nuclear)	Ed Armstrong (Exelon)	Bo Cheng

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International Participation

2004 Members

US (19 utilities, 80 units)		International (9 utilities, 113 units)
AmerenUE	Pacific Gas & Electric Co.	EdF (France)
Constellation Energy	PPL Corporation	Japan Atomic Power Co. (Japan)
Detroit Edison	Public Service Elec. & Gas	Kansai Electric Power Co. (Japan)
Duke Energy	So. Tx. Project Nucl. Oper. Co	Kyushu Electric Power Co. (Japan)
Energy Northwest	Southern California Edison Co	Leibstadt (Switzerland)
Entergy	Southern Nuclear Operating	Shikoku Electric Power Co. (Japan)
Exelon	Tennessee Valley Authority	Tokyo Electric Power Co. (Japan)
FirstEnergy Corp.	TXU Electric	UNESA (Spain)
Nuclear Management Corp	Wolf Creek Nucl. Oper. Corp	Vattenfall (Sweden)

Close Collaboration with

INPO; NEI; NRC Research; Global Nuclear Fuel; Westinghouse and Framatome ANP

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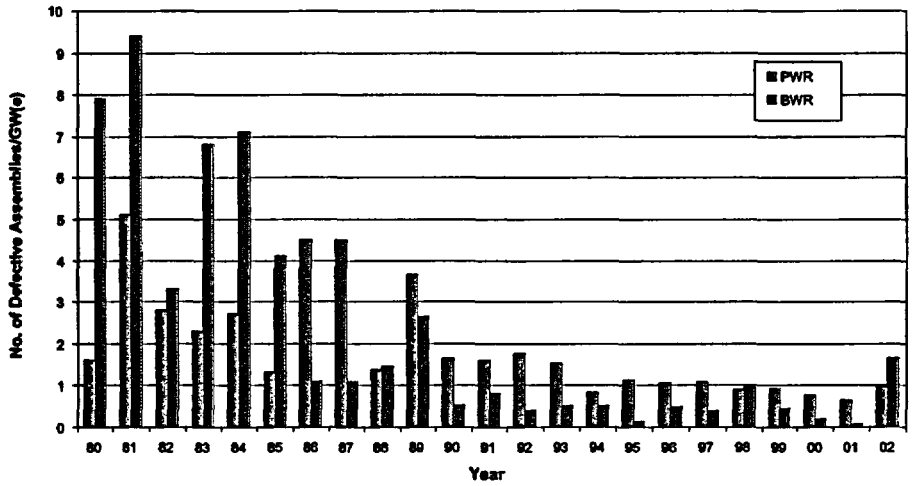
Key Issues Addressed

Key Fuel Performance Issues

- BWR :
  - Large number of BWRs experiencing fuel failures, and many of the root causes are unknown
  - Needs to assess the impact of Noble Metal Chemical Application (NMCA) and Zn injection on fuel performance
  - Excessive channel bow interferes with control blade insertion at some BWRs
- PWR :
  - Grid-rod fretting continues to be the main failure root cause
  - Axial offset anomaly (AOA) persists but occurrence frequency and severity are down significantly
  - RCCA cracking and deformation

Fuel Failure Trend 1980 To 2002



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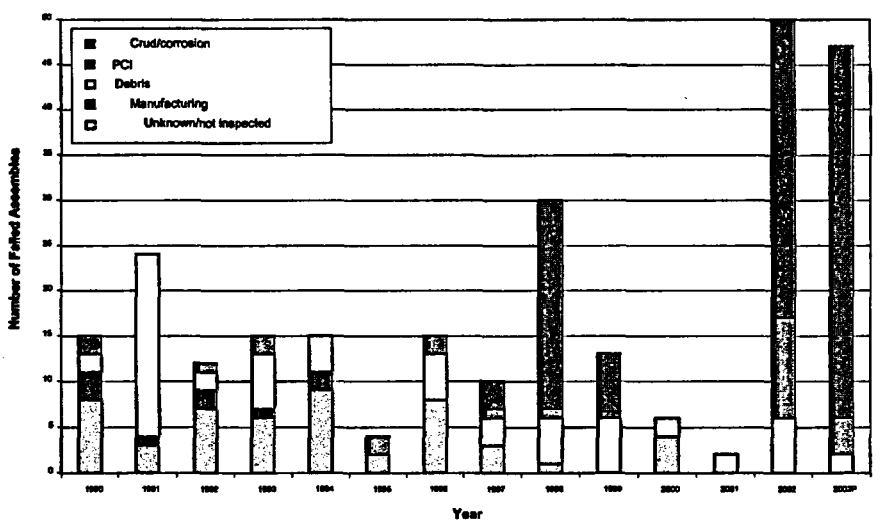
Trend In BWR Fuel Failure Root Causes



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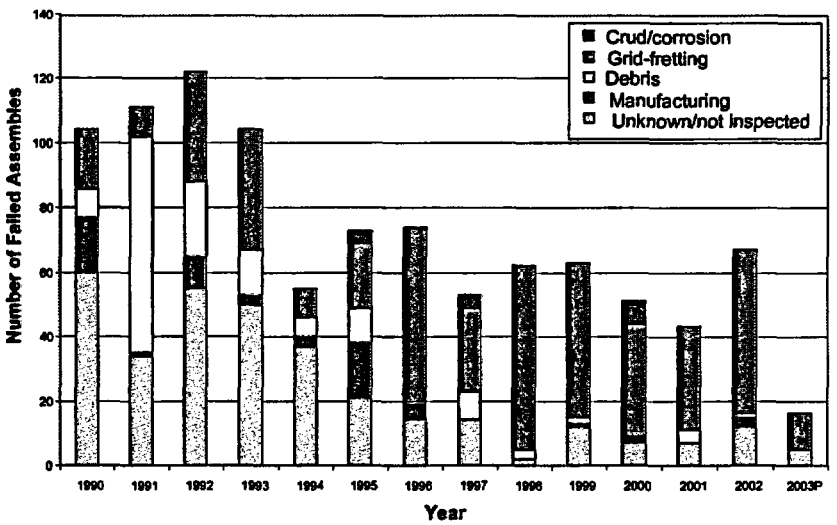
Trend In PWR Fuel Failure Root Causes



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RFP Focus

- Resolve existing operation and reliability problems
  - Failure root cause investigations
    - Two hot cell shipments planned in late 2003 to identify BWR failure root causes
    - Assisted members in failure root cause investigations
  - Impact of NMCA and Zinc injection on fuel performance
    - Data indicate apparent increase in clad corrosion and crud
    - Collect data to quantify the impact
    - Work with BWRVIP and Chemistry group to issue guidelines
    - Conduct tests to identify alternatives
  - Mitigate axial offset anomalies (AOA) and crud deposits
    - Interim mitigation measures available-UT cleaning, reload core design, chemistry control, mitigation tool available (BOA code)
    - Potential solutions are being investigated

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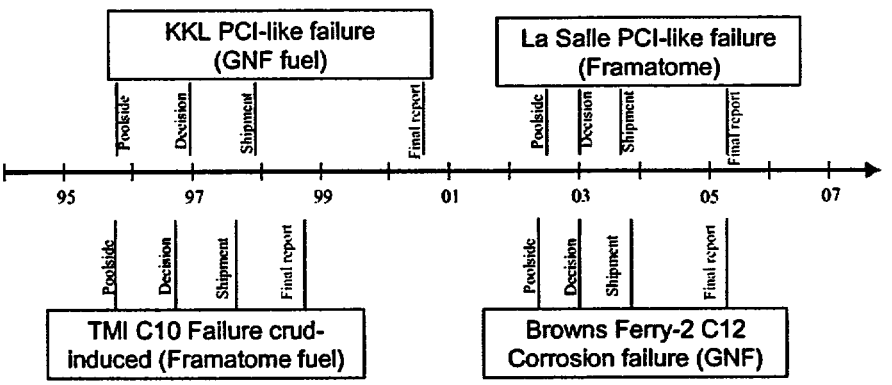
Hot Cell Projects To Determine Failure Root Cause



Hot cell exams have been successful in identifying failure root causes

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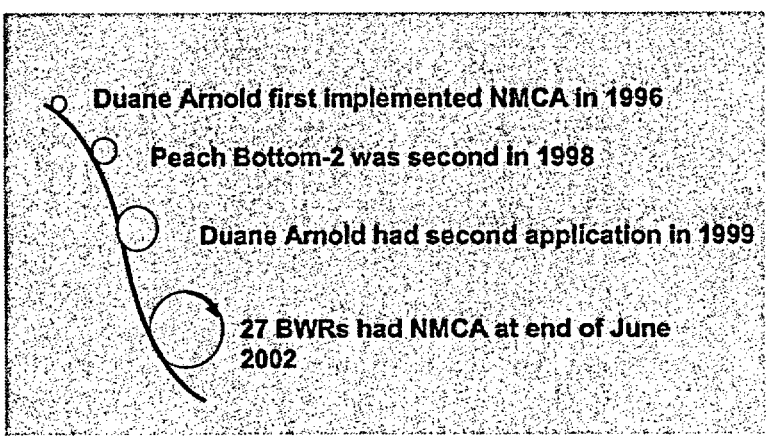
NMCA Implementation Status



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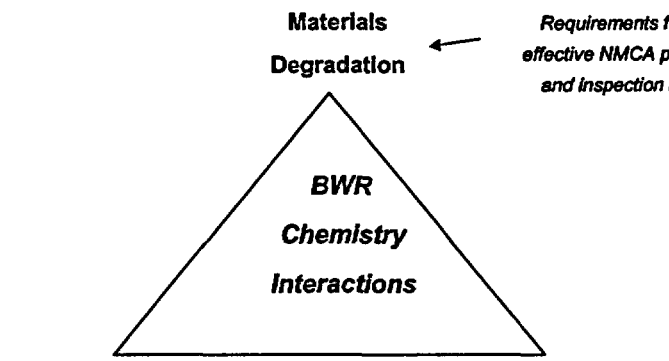
BWR Chemistry Optimization



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RFP Focus (cont'd)

- Proactively collect data to ensure margins under high duty conditions
  - No data available for modern high-duty fuel
  - Minimum number and scope hot cell campaigns performed/planned
  - The data are crucial to ensure margins AND can also be used for burnup extension
- Regulatory stability
  - NRR wants improved technical basis for licenses already granted
  - RES and regulatory agencies worldwide are funding research to revise regulatory criteria for RIA & LOCA
    - RFP submitted a RIA Topical to NRC for review in 2002
    - RFP is working closely with NRC to develop the LOCA criteria for advanced high burnup fuel

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Quantify Operating Margins By Hot cell Exams

Quantify margins of key fuel designs under prototypical and limiting conditions by examining fuel with

- Minimum time to reach practical discharge limits (i.e., achievable within 5% enrichment limit)
  - High power
  - Long cycles
- Representative water chemistry
- High temperature (PWR)

The program is designed to avoid the really big surprises!

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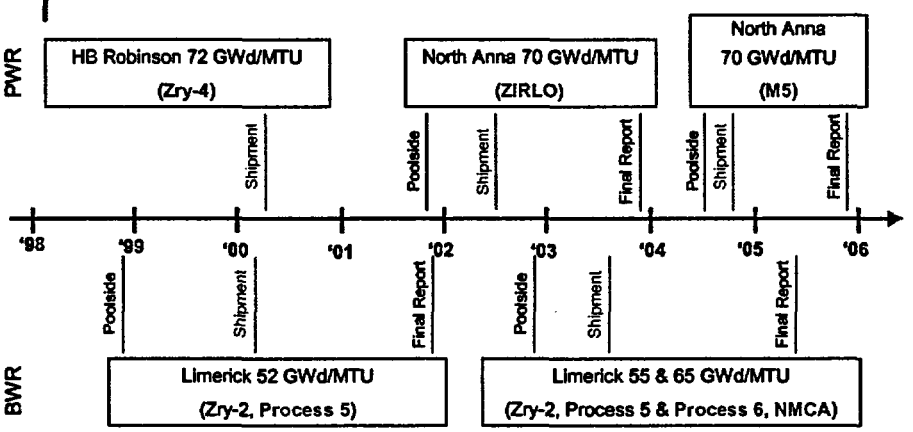
Hot Cell Projects To Quantify Margins



Major designs covered with minimum number of programs

All hot cell exams complete in 2006

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Strategies: Ultrasonic Fuel Cleaning

PWRs that have now ultrasonically cleaned fuel:

Callaway

Purpose: AOA avoidance

- Callaway experienced varying degrees of AOA from Cycle 4 through 11. In combination with reducing fuel duty, CY12 was free of AOA and CY13 has had no indications through 7500 MWD/MTU

South Texas Project Unit 1

Purpose: AOA avoidance, allowed a reduction in fuel assembly purchases

- First cleaning performed in October 2002

South Texas Project Unit 2

Purpose: AOA avoidance following SG replacement & up-rate, allowed a reduction in fuel assembly purchases

- First cleaning performed in April 2003

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Strategies: Ultrasonic Fuel Cleaning

Next PWR planning to ultrasonically clean fuel:

Vogtle Unit 1

Planned Date: October 2003

Purpose: AOA avoidance (in anticipation of injecting Zn) and dose rate reduction

First BWR planning to ultrasonically clean fuel:

Quad Cities Unit 2

Planned Date: Spring 2004

Purpose: *Dose rate reduction*

- Mock-up testing taking place at Vallecitos, 16 discharged assemblies will be cleaned on a pre-trial basis in Fall 2003. Anticipate cleaning first reload assemblies in Spring 2004.

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Mission Of WG2 (Response To Transients)

RFP WG2 is the industry's interface with NRC on fuel related regulatory and technical issues

NRR

-Through NEI on regulatory and licensing issues

RES

-MOU between EPRI and RES

>LOCA tests in ANL

>Cabri International Program

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Three Main Regulatory Focus Areas

- **RIA**
  - Submitted RIA Topical Report on licensing criteria at high burnup (for Zr-4)
  - Participated in the Cabri International Project to confirm margins
- **LOCA**
  - Work with NRC to define appropriate LOCA limits for high burnup fuel rods
  - Tests on representative high-burnup rods and LOCA tests in Japan, France and Norway
  - LOCA response of advanced claddings (eg. Zirlo, M5)
- **Industry Guide for licensing burnup extensions**
  - Identify burnup-dependent fuel design criteria and how to demonstrate compliance at high-burnup

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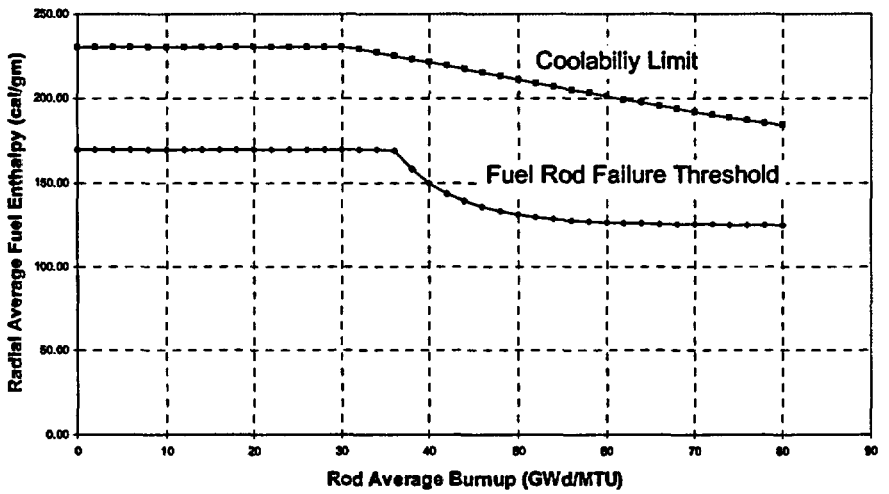
Proposed RIA Criteria



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Ongoing LOCA Experimental Programs

- Four major international experimental LOCA programs
  1) **NRC-ANL LOCA** criteria-related tests on irradiated fuel
     - Industry collaborate closely with NRC
       - Provided Robinson and Limerick high-burnup rods and un-irradiated Zircaloy archive material from Robinson, Limerick
       - Framatome and W provided M5 and Zirlo
       - Selected tests with irradiated M5 and Zirlo
  2) **Separate-effects tests at EDF/CEA** in France on unirradiated & pre-hydrided Robinson and Limerick claddings (RFP funded) as well as M5 and Zr-4 to study oxidation, quench and phase transformation kinetics
  3) **JAERI LOCA** test program (ALPS) on irradiated fuel
  4) **HALDEN LOCA** tests using high burnup fuel rods

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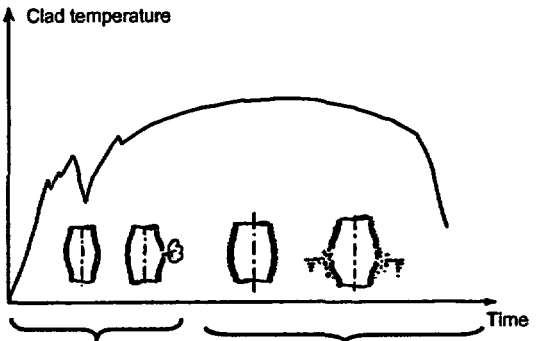
Separate Effects Tests- Collaboration With EdF



EDGAR-RFP
- Metallographic characterization
- Mechanical properties

CINOG-RFP
- Oxidation tests
- quench tests

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Industry Guide For Burnup Extension

- Being prepared in response to NRC's mandate for an industry-wide, consistent approach to the licensing of burnup extensions
  - 75 GWD/T rod average for PWR and 70 GWD/T for BWR
- Approach :
  - Reviewed current criteria and design limits (SRP 4.2 and non-proprietary vendor topicals) – Determined which criteria depend on burnup
  - Determine what changes (if any) are needed and what data will be required to demonstrate compliance with the new limits
- Status :
  - The draft Industry Guide is complete except for LOCA-dependent "cladding residual ductility" criterion
  - The LOCA section is being drafted by a "focus group" including utilities and vendor LOCA experts
  - To be submitted to NRC in 2004

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Summary

- Active International participation
- Have addressed several key industry operational and technical issues and are well-positioned to obtain data to ensure margins and avoid big surprises
  - UT cleaning and AOA model & guidelines
  - NMCA data and BWR water chemistry guidelines on NMCA & Zn concentrations
  - RIA Topical report
- Robust Fuel Program is aimed to ensure
  - Reliable and efficient fuel operations
  - Industry wide collaboration to resolve safety & regulatory issues in an integrated and effective manner

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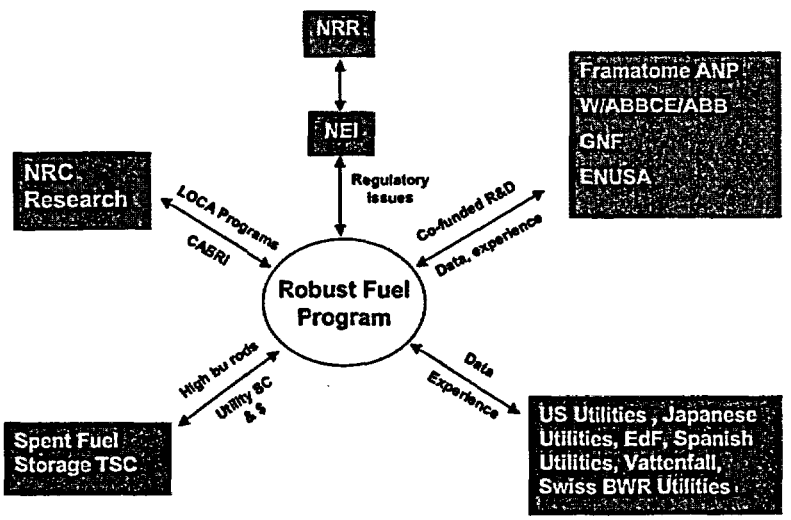
Industry Interactions



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Ultrasonic Fuel Cleaning Technology

NRR

Washington D.C.

October 1, 2003

J Deshon
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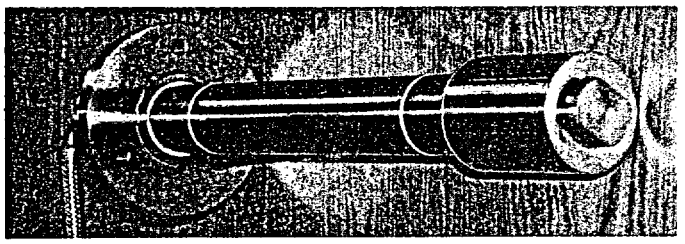
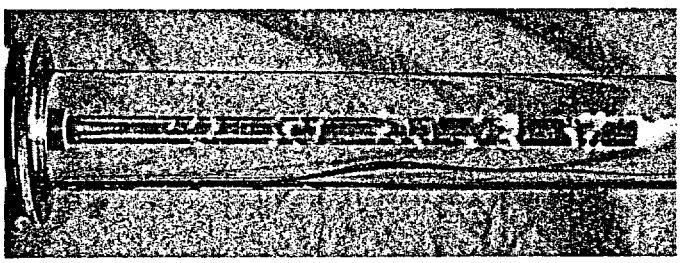
Fuel Cleaning Technology Background

- Identified advanced ultrasonics technology for this use (1997)
  - Omni-directional ultrasonic field provides enhanced bundle penetration efficiency
- Commissioned mockup testing facility and began development of QA testing procedures (1998)
- Confirmed fuel pellet integrity (1999)
  - Cladding vibration amplitudes measured in mockup facility
  - Cladding vibrations bounded by normal operating flow-induced vibration amplitudes
  - Fuel vendor review, concurrence obtained
  - No problems during Callaway start-up ramps & trip (November 1999)
- Manufactured and deployed single channel commercial prototype system at Callaway (1999) – to demonstrate technology with crud reduction and AOA avoidance in mind

Fuel Cleaning System Employs Advanced Ultrasonic Transducers

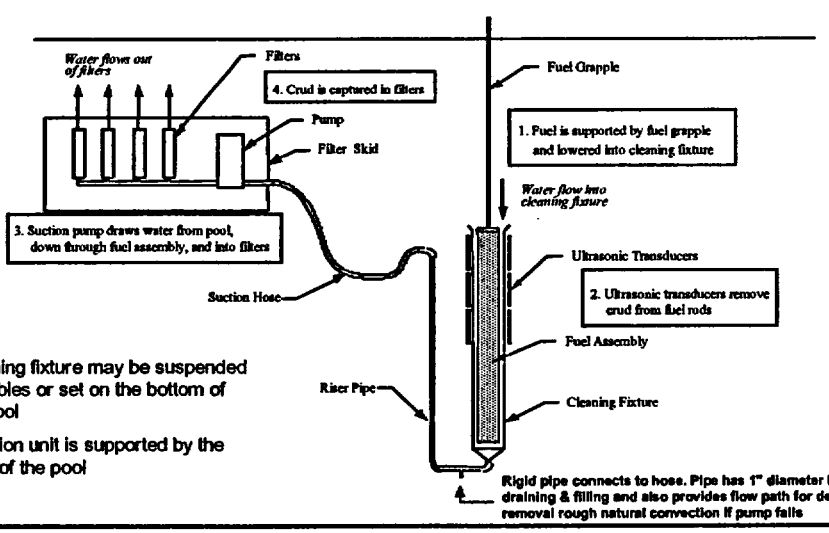


Push-pull transducer



Omni-directional energy field enhances bundle penetration

Schematic of Ultrasonic Fuel Cleaning System



Cleaning fixture may be suspended by cables or set on the bottom of the pool

Filtration unit is supported by the edge of the pool

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Callaway Plant 50.59 Evaluation

- Thermal-hydraulic analyses of forced and natural convection cooling of hot fuel assembly
- All seismic issues satisfied
- Fuel Pellet and cladding vibrations are bounded by normal operating flow-induced vibration amplitudes
- Fuel vendor review completed, concurrence obtained

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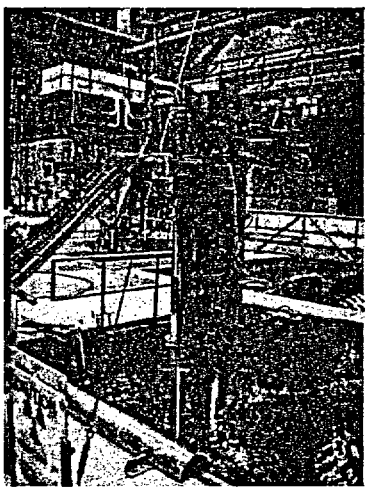
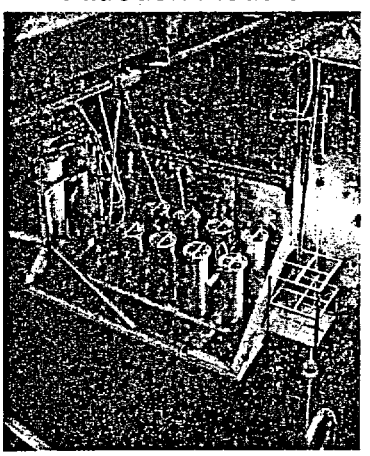
Installation of Prototype Fuel Cleaning System: Callaway

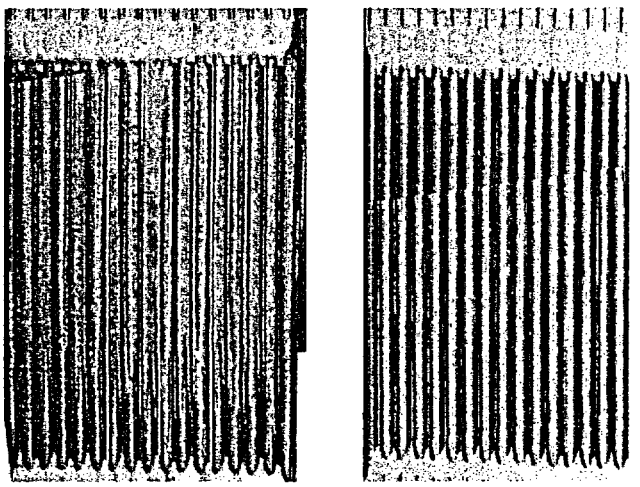


Cleaning Module

Filtration Module



Demonstration Cleaning at Callaway
(16 reload assemblies during RF10, October 1999)



Before *After*

Robust Fuel Program

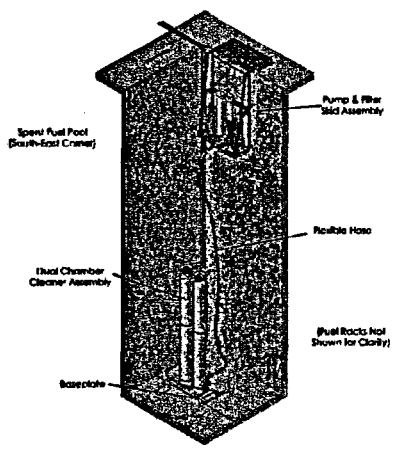
Fuel Cleaning Continues at Callaway

- Endorsed by plant management for Refuel 11 & 12:
  - To Eliminate AOA risk on high duty, second cycle fuel
  - To Reduce risk of early AOA onset on feed fuel by eliminating redistribution of reload CRUD from low to high peaking assemblies
  - To Control particulate inventory long term, recognizing that high duty fuel deposits do not effectively dissolve by established shutdown chemistry evolutions
  - To Minimize personnel radiation exposure during refueling outages, recognizing that lower particulate inventory results in lower shutdown radiation fields

Fuel Cleaning Performance at Callaway

- Safe and efficient demonstration of production cleaning in spent fuel pool
- Equipment operating procedures field proven
- 10CFR50.59 approved by plant safety review committees
- No adverse radwaste releases
  - No HP alerts
  - Acceptable filter handling and storage
- Outstanding plant staff efforts

Advancements in Ultrasonic Fuel Cleaning Design



- The second generation fuel cleaner is a dual chamber, free standing design.
- Each chamber includes a transducer basket assembly installed inside a reflector housing.
- Vertically mounted transducers on all sides were used in this design vs. horizontally mounted transducers on two opposing sides in the Callaway design, allowing ten transducers to be used for effective cleaning vs. sixteen for Callaway.

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Advancements in Ultrasonic Fuel Cleaning Design

- A dual chamber design allows one assembly to be inserted and cleaned while the spent fuel bridge operators return the previously cleaned assembly to its storage location in the spent fuel racks.
- Software records all of the monitored data points for each fuel assembly, including the incremental change in filter dose rate. This data along with activity analysis of cleaner effluent samples drawn during the cleaning allow for a curie removal mapping for the core. This information may be helpful to the plant staff in determining where the crud is building up on the core.

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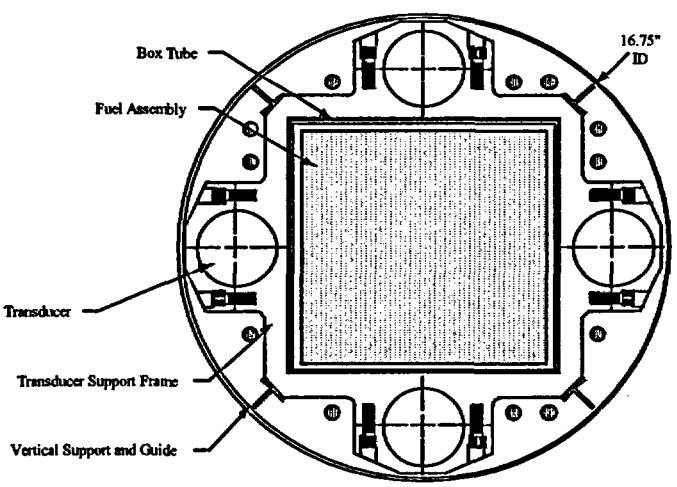
Fuel Cleaning System

Cleaning Fixture Internal Cross Section



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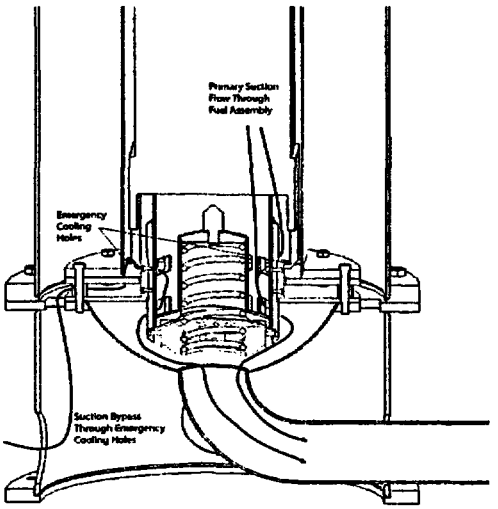
Cooling Safety Feature (dual channel)



- For the dual channel system, emergency cooling ports have been provided at the bottom of each cleaning fixture to allow natural convection (driven by the decay heat of the fuel). This was done to ensure flow would be supplied only the channel in use.
- Using bounding assembly and decay heat conditions, engineering calculations demonstrate that the maximum clad temperature achieved while in the natural circulation mode is well below DNB.