



Zircaloy-BWR Fuel Channel Irradiation Program Pre-Submittal Meeting

AREVA/NRC Meeting
Rockville, MD
May 12, 2015



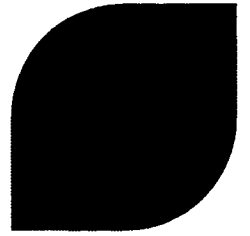


Zircaloy-BWR Fuel Channel Irradiation Program Pre-Submittal Meeting

Dr. Kevin Mon
Advisory Engineer
AREVA BWR Materials
Richland, Washington

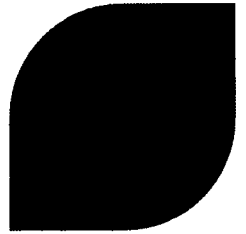


Agenda



- ▶ **Objectives**
- ▶ **Topical Report (TR) Technical Content**
- ▶ **Summary**
- ▶ **Next Steps**

Presentation Objectives

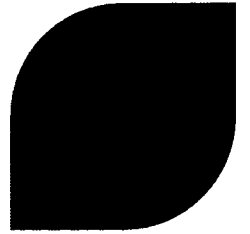


► Present TR technical content and Licensing Approach

- ◆ Zry-BWR Fuel Channel (FC) Irradiation Program
- ◆ Zry-BWR Material Description
- ◆ Zry-BWR Experience Base

► Obtain NRC feedback on TR technical content and approach

Topical Report Objectives

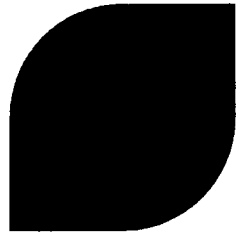


- ▶ **Request NRC approval for Zry-BWR FC Irradiation Program**

- ▶ **Request approval for Licensing Approach used for Zry-BWR FC Irradiation Program**
 - ◆ **Zry-BWR FCs licensed using previously-approved methods and conservative assumptions**
 - ◆ **Supplemental surveillance requirements**

- » **Resolve industry safety issue in timely manner**

Zry-BWR FC Irradiation Program Goals



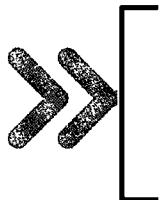
► Resolve CB interference safety issue



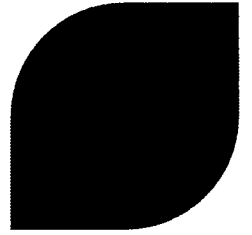
► Acquire additional data and operational experience with Zry-BWR FCs

- ◆ Growth, bulge, bow, corrosion

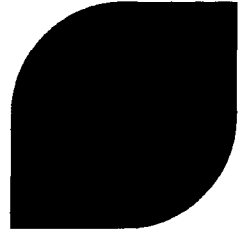
► Bridge gap between leads and full reloads



Zry-BWR FC Irradiation Program Basis for Requested Number of FCs



Zry-BWR FC Irradiation Program Surveillance Program



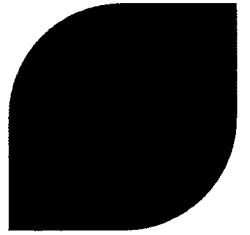
► Current FC bow management techniques still used

- ◆ Plant Technical Specifications typically require scram-time testing of 10% of control cells every 120 days**



» Supplemental surveillance will detect potential stuck CBs or unanticipated behavior

Zry-BWR FC Irradiation Program Post Irradiation Examination Plan

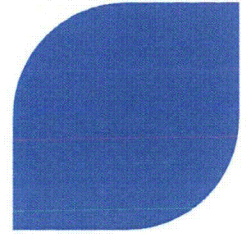


- ▶ **PIE from existing Lead Fuel Channels
[] will provide quantitative
performance data in advance of Program FCs**

- ▶ **Industry standard PIE practices for performance
surveillance will apply to Program FCs**
 - ◆ **Examinations typically include growth, bulge, bow, corrosion**

- » **Existing LFCs will provide sufficient PIE data to
quantify Zry-BWR performance**

Presentation Objectives



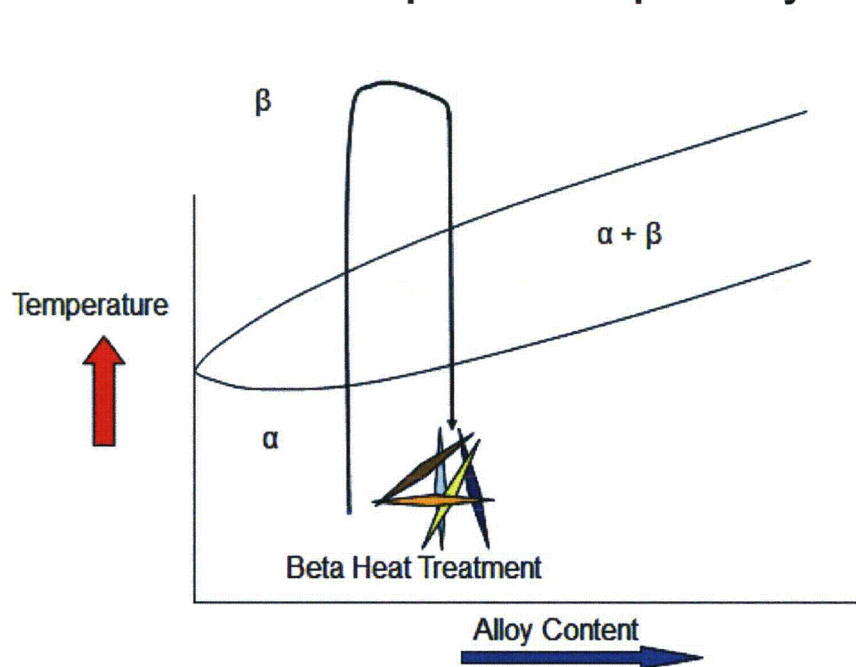
- ▶ **Present TR technical content and Licensing Approach**
 - ◆ Zry-BWR Fuel Channel (FC) Irradiation and Monitoring Program
 - ◆ **Zry-BWR Material Description**
 - ◆ Zry-BWR Experience Base

- ▶ **Obtain NRC feedback on TR technical content and approach**

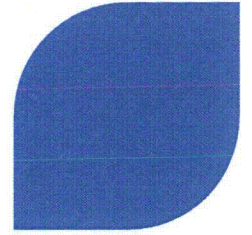
Zry-BWR FC Irradiation Program Fuel Channel Materials

- Zry-BWR Irradiation Program will use FCs in the recrystallized (Zry-BWR RXA) or Beta-Quenched (Zry-BWR BQ) final form

- ◆ For Zry-BWR BQ, FC sheets are given BQ heat treatment
- ◆ Results in quasi-isotropic lathy microstructure



Zry-BWR Composition

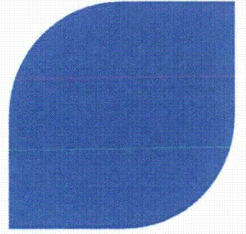


- ▶ **Zry-BWR has similar composition to Zry-4**
 - ◆ Slightly higher Fe and Cr contents
 - ◆ No new alloying elements



» **Small compositional change relative to Zry-4**

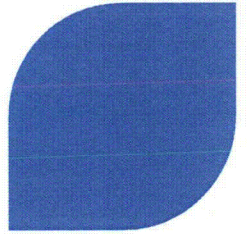
Zry-BWR Manufacturing Process



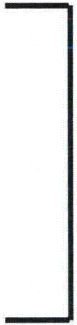
- ▶ **Zry-BWR RXA and BQ sheet manufacturing process similar to current FCs**
 - ◆ For BQ, sheets are given BQ heat treatment []
 - ◆ Similar SPP coarsening and stress relief treatments
- ▶ **No differences in later FC manufacturing steps**
- ▶ **All FCs have same final FC product specification**

» **Zry-BWR RXA and BQ have similar manufacturing to current FCs**

Zry-BWR Mechanical Properties

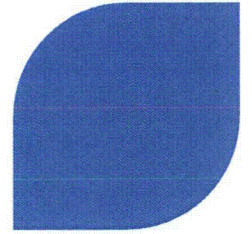


- ▶ Both Zry-BWR RXA and Zry-BWR BQ meet or exceed minimum mechanical properties in EMF-93-177 Rev. 1 and ASTM B352/B352M



- » Approved mechanical analysis methods are applicable to Zry-BWR RXA and BQ FCs

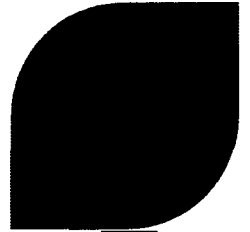
Presentation Objectives



- ▶ **Present TR technical content and Licensing Approach**
 - ◆ Zry-BWR Fuel Channel (FC) Irradiation and Monitoring Program
 - ◆ Zry-BWR Material Description
 - ◆ **Zry-BWR Experience Base**

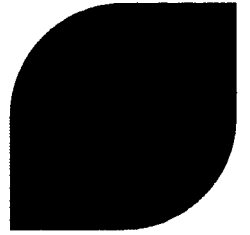
- ▶ **Obtain NRC feedback on TR technical content and approach**

Zircaloy-BWR Fuel Channel Irradiation Experience



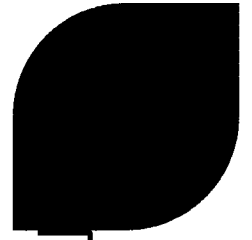
Zry-BWR RXA and BQ LFCs have shown excellent performance

Zircaloy-BWR Fuel Channel Additional Irradiation Experience



»» Extensive leads program underway

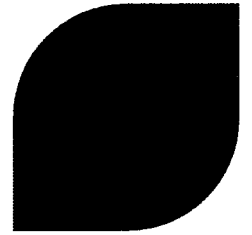
Zry-BWR Fuel Channel Corrosion



Zry-BWR FC corrosion will not exceed that of existing FCs

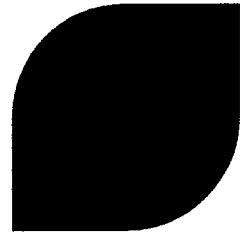


Zry-BWR Irradiation Experience Corrosion



Corrosion of Zry-BWR lower than Zry-4

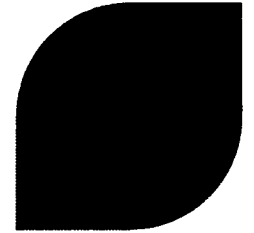
Zry-BWR Irradiation Experience Hydrogen Uptake



H uptake of Zry-BWR lower than Zry-4



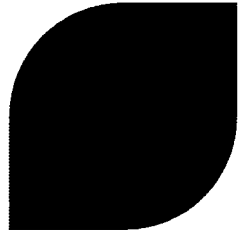
Zry-BWR Fuel Channel Irradiation Growth



- ▶ Zry-BWR RXA LFCs exhibit low growth
- ▶ Zry-BWR BQ LFCs exhibit lower growth

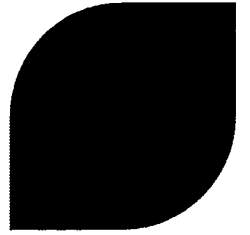


Zry-BWR Fuel Channel Bulge



**Zry-BWR RXA and BQ bulge performance will be modeled
with current methods for this irradiation program**

Zry-BWR Fuel Channel Bow



► Zry-BWR LFCs exhibit no abnormal bow

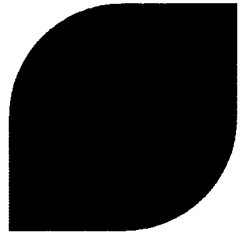
- ◆ Zry-BWR RXA bow consistent with model
- ◆ Zry-BWR BQ bow [

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Zry-BWR RXA and BQ bow will be evaluated with current model for this irradiation program

Licensing Analysis Conclusions

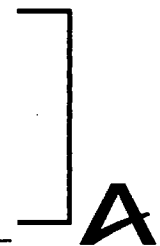
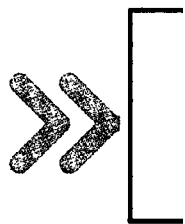


► Zry-BWR RXA and BQ LFCs have

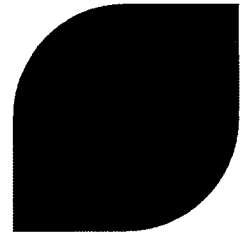
- ◆ Similar composition and fabrication process as existing FCs
- ◆ Mechanical properties that meet or exceed those of existing FCs

► Data from Zry-BWR LFCs show

- ◆ Corrosion, bulge, bow within range of existing FCs
- ◆ Low irradiation growth
- ◆ BQ heat treatment leads to decreased growth and improved bow performance

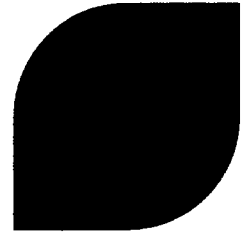


Zry-BWR FC Irradiation Program Conclusions



- ▶ **Surveillance Program will ensure safe operation of FCs in the Zry-BWR FC Irradiation Program**
- ▶ **Zry-BWR LFCs will reach EOL before Zry-BWR FC Irradiation Program FCs**
- ▶ **If Surveillance Program or PIE indicate a safety problem, Zry-BWR FCs can be replaced as needed**
- » **Zry-BWR FC Irradiation Program is not a challenge to safe reactor operation**

Next Steps



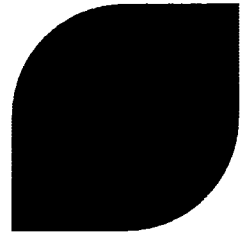
- ▶ Submit TR to NRC – []
- ▶ Post-Submittal meeting/technical audit – []
- ▶ RAI – []
- ▶ RAI response – []



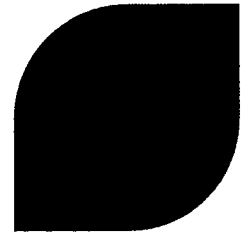
NRC approval is requested by



Discussion / NRC Feedback



Acronyms/Nomenclature



ASTM	American Society for Testing and Materials
BOL	Beginning of Life
BQ	Beta-quench
BU	Burnup
BWR	Boiling Water Reactor
CB	Control Blade
EOL	End of Life
FA	Fuel Assembly
FC	Fuel Channel
HC	Hot Cell
LFC	Lead Fuel Channel
MWd/kgU	MegaWatt days per kilogram Uranium
NRC	Nuclear Regulatory Commission
PIE	Post Irradiation Examination
RAI	Request for Additional Information
RXA	Recrystallized Annealed
SPP	Second Phase Particle
TR	Topical Report
Zry	Zircaloy



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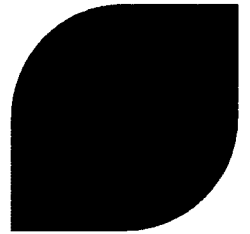


Zry-BWR Fuel Channel Irradiation Program: Overview

Jeff Morris, Manager
Materials & Thermal-Mechanics
Richland, Washington

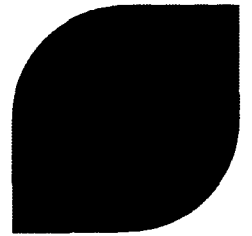


Meeting Agenda



- ▶ **Provide overview of proposed Zry-BWR Fuel Channel Irradiation Program**
- ▶ **Present the technical content of the Zry-BWR Fuel Channel Irradiation Program topical report (TR)**
- ▶ **Obtain NRC feedback on program, technical content of the TR, and review schedule**

Timeline



- ▶ **TR for full reload application was submitted in December 2014, but withdrawn after March 2015 meetings with the NRC**

- ◆ [

- ◆

- ◆

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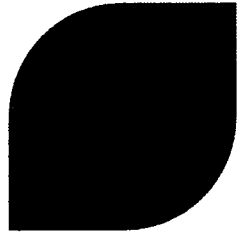
- ▶ **New TR employs concept of restricted supply in combination with supplemental surveillance**

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- ◆

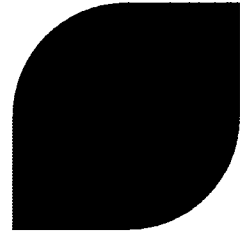
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Irradiation Program Objectives



- ▶ **Obtain safety benefits by resolving control blade (CB) interference issues through use of Zry-BWR fuel channel (FC) material**
- ▶ **Acquire additional data and operational experience with Zry-BWR fuel channels**
- ▶ **Bridge gap between leads and full reloads**

Irradiation Program Definition

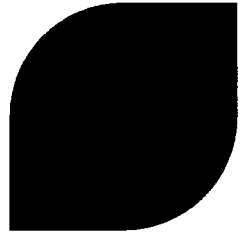


► Program restricts quantities and adds supplemental surveillance requirements

- ◆ Quantity is reduced to the minimum amount required to resolve the current safety issue with control blade interference
- ◆ Supplemental surveillance requirements are imposed to ensure detection of unanticipated behavior
- ◆ PIE from lead channels continues to be gathered and reviewed to verify acceptable performance of Zry-BWR

► Zry-BWR channels must be same channel type as used on reload

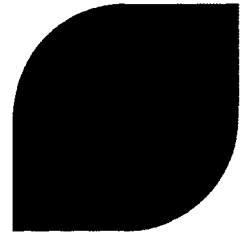
Quantity Restriction



- ▶ **Safety issue can only be resolved by placing bow-resistant Zry-BWR channels []**



Supplemental Surveillance Requirements



► **TS scram testing requirements and industry guidelines (GEH SC11-05) define test frequency and acceptable control rod drive forces**

► **AREVA will require a supplemented test population to include:**

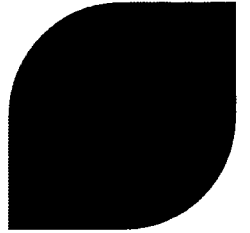
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» **Supplemental surveillance will identify unanticipated behavior**

Lead Fuel Channel PIE



► **PIE data continues to be gathered from lead channels**

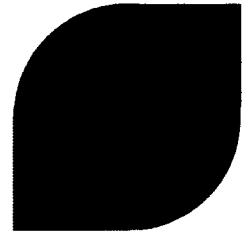
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» **PIE data from lead fuel channels will be evaluated to verify performance**

Licensing Approach



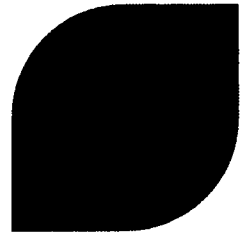
► **Approved methods for channel stress, bow, bulge, growth, and corrosion**

- ◆ **Reload channels will be supported by analyses of record using the approved methods**
- ◆ **TR justifies conservative application of approved methods to Zry-BWR channels based on material properties, specifications, and PIE data from leads**

► **License Amendment Request not required**

- ◆ **Fuel channel methods do not support any COLR limits**
- ◆ **Utilities can employ the Zry-BWR Irradiation Program under a 10 CFR 50.59 evaluation once TR is approved**

Conclusions



► Irradiation Program bridges the gap between lead channels and reload supply

- ◆ Safety issue with control blade interference resolved quickly

► Irradiation Program provides for additional in-core validation while mitigating risk

- ◆ Quantity restricted
- ◆ Supplemental surveillance required
- ◆ PIE data from lead channels reviewed

► Approved TR provides clear licensing basis for utilities

» Irradiation Program provides near term safety improvement and minimizes risk of unanticipated behavior