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General Perspective on Development of Revised RIA Criteria

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Revised RIA Criteria – General Perspective

- Development of revised criteria for high-burnup fuel is a challenging objective
- Industry has proposed modified criteria in Topical Report (EPRI 1002865)
- We understand the NRR concerns about our treatment of uncertainties expressed in Safety Evaluation Letter (SEL)
- Industry provided detailed responses to SEL questions, and
- Is developing alternative approach to addressing uncertainties / Can discuss in general terms at this meeting.
- We appreciate the opportunity presented by this workshop to discuss issues

Industry General Concerns

- Interim criteria should not be applied to current plants
- Concerned about the timing proposed for the interim criteria
  - Judgments likely to be based on incomplete evidence
  - Conflicting interpretations exist for available data
  - Disagreement exists about underlying basic assumptions, and
  - There are alternative interpretations available
  - RIL 0401 would have a significant impact on operations
- The interim criteria should not be based solely on RIL-0401 analysis

Industry Perspective

- REA/RDA is an extremely low probability event
  - Low probability of mechanical failures that could lead to rod drop/rod ejection
  - + Limited period of susceptibility within a cycle
    - BWRs: startup, approach to criticality, power less than 5%
    - PWRs; EOC startup (not likely to have fully inserted rods)
- Yet, excessive conservatism in criteria will have a real impact on core designs
  - Analysis must address limiting conditions
  - Flatter designs (to reduce rod worth) ⇒higher fluence on PV
  - Need for reduced cycle lengths / reduced efficiency
- Excessive conservatism in this area will not enhance overall safety

Issues with Criteria Based on RIL 0401

- The RIL 0401 Failure threshold is based on two questionable assumptions without supportive evidence:
  - Highly spalled cladding with significant oxide blisters behaves the same as unspalled cladding and such cladding is representative of current fuel at high burnup
  - Under the same enthalpy input, MOX fuel pellets will cause the same amount of PCMI on cladding as UO2 pellets
- The RIL 0401 failure threshold is anchored around 3 CABRI test failures (2 highly spalled, one MOX)

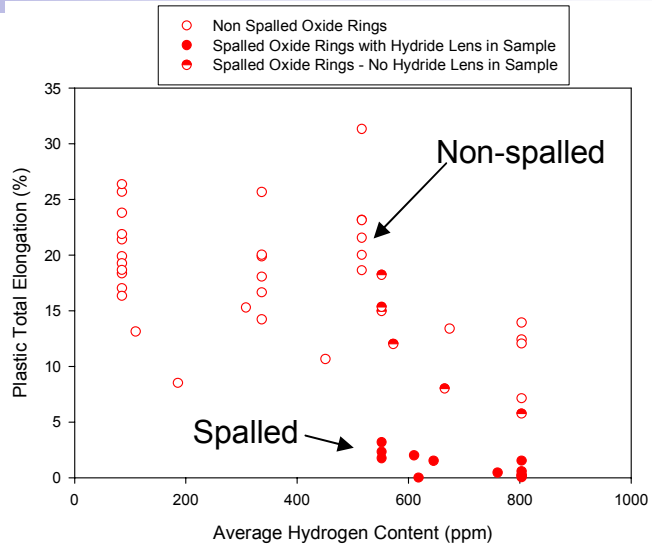
Issues with RIL 0401 (continued)

- Both assumptions are inconsistent with evidence reported by IRSN and elsewhere
  - Ductility of highly spalled cladding with hydride blisters is a factor of 2 to 3 lower *(Ref: IRSN paper on PROMETRA experiments in ASTM Journal, June 2005 / Also NFIR data provided in responses to SEL)*
  - The formation of a rim structure is considerably different in MOX fuel fabricated by the MIMAS procedure (as used in CABRI tests)
    - High-enriched (~24%) PuO2 grains embedded in a depleted UO2 matrix
    - Rim formation not on pellet periphery but throughout the pellet around PuO2 grains
    - For sited test this results in greater FG inventory on grain boundaries & increased PCMI *(Ref: IRSN Synthesis Paper of CABRI REP-Na Program submitted for publication in Nuclear Technology)*

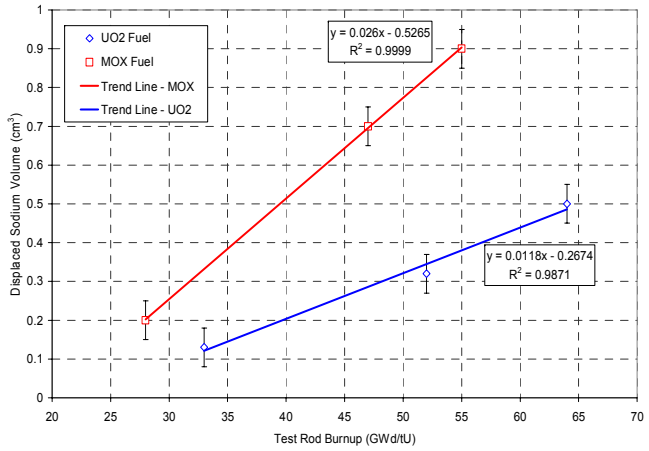
Evidence from Experiments

(Included in Responses to SEL)

Mechanical property data from burst tests on spalled and unspalled specimens (NFIR)



Displaced Sodium Volume by MOX and UO_2 Rods tested at CABRI Facility



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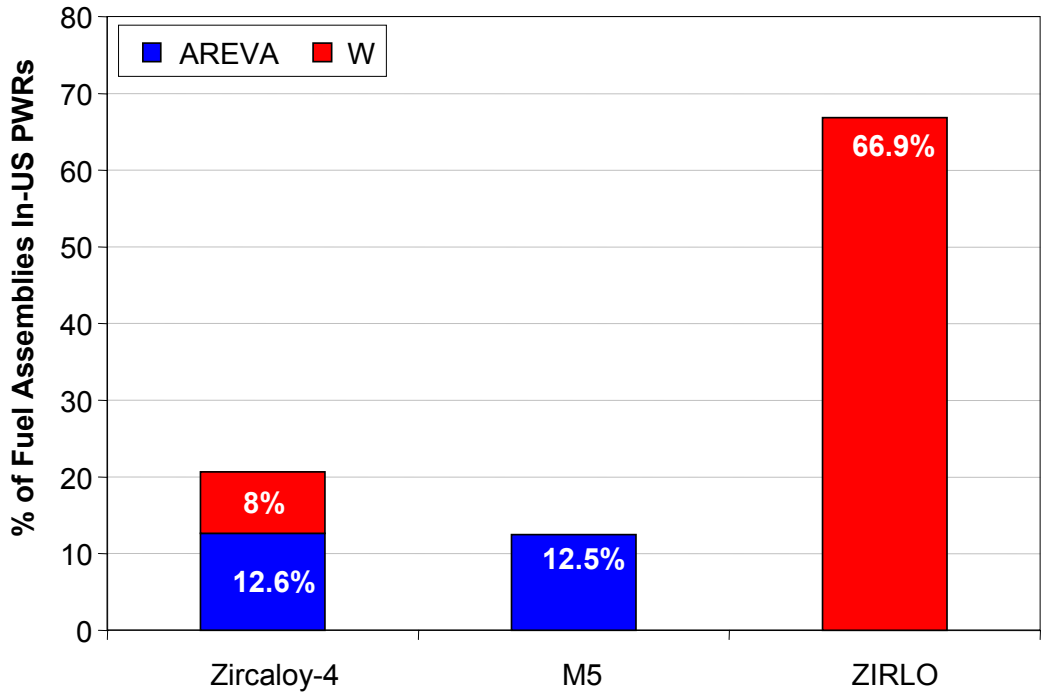
Occurrence of Spallation

- Observed on standard (non-optimized Sn) Zr-4 cladding
- Experienced in isolated cases during operation (High-temperature plants) for low Sn cladding
- Remedied by switching to advanced claddings
- Optimized Zr-4 less susceptible
- Not observed on Zirlo cladding even at very high corrosion levels (Vandellos rods)
- Not observed on M5 cladding at very high burnup and not an issue (not enough hydrogen to form blisters even at EOL)
- Could be addressed on a probabilistic basis

Current Inventory of Cladding Types in US PWRs



- All currently utilized Zirc-4 cladding is “low-tin”
- Performance of “low-tin” Zr-4 is better under the same operating conditions
- All CABRI RIA test failures in UO2 fuel involved fuel with obsolete cladding

BWR Criteria

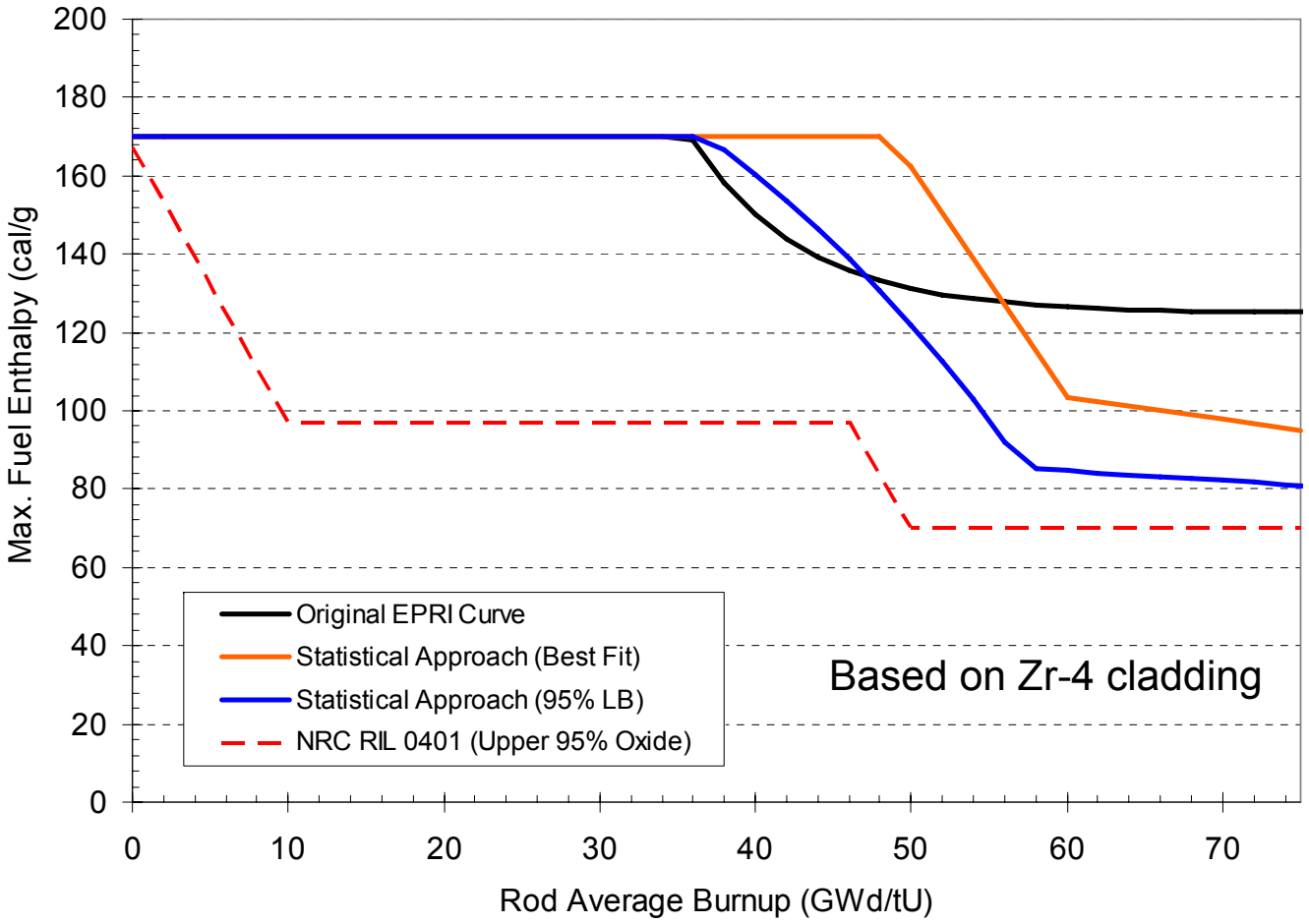
- BWR cold conditions need special consideration
  - Pulse shape in BWRs is different at lower temperatures: Prompt component & delayed component (at 80 C prompt is 50% of total)
  - During response to delayed component cladding temperature is no longer cold
    - Improved cladding ductility due to increased temperature (disagreement with RIL 0401)
  - Possibly 2 different cladding failure modes (PCMI and ballooning)
  - NSRR data is representative of prompt component only
  - Will address in greater detail later in this workshop

The Coolability Limit

- For the interim, the coolability limit needs to be based on physical considerations
  - Potential for energetic fuel material release
  - Data and evaluation of the consequences of released material

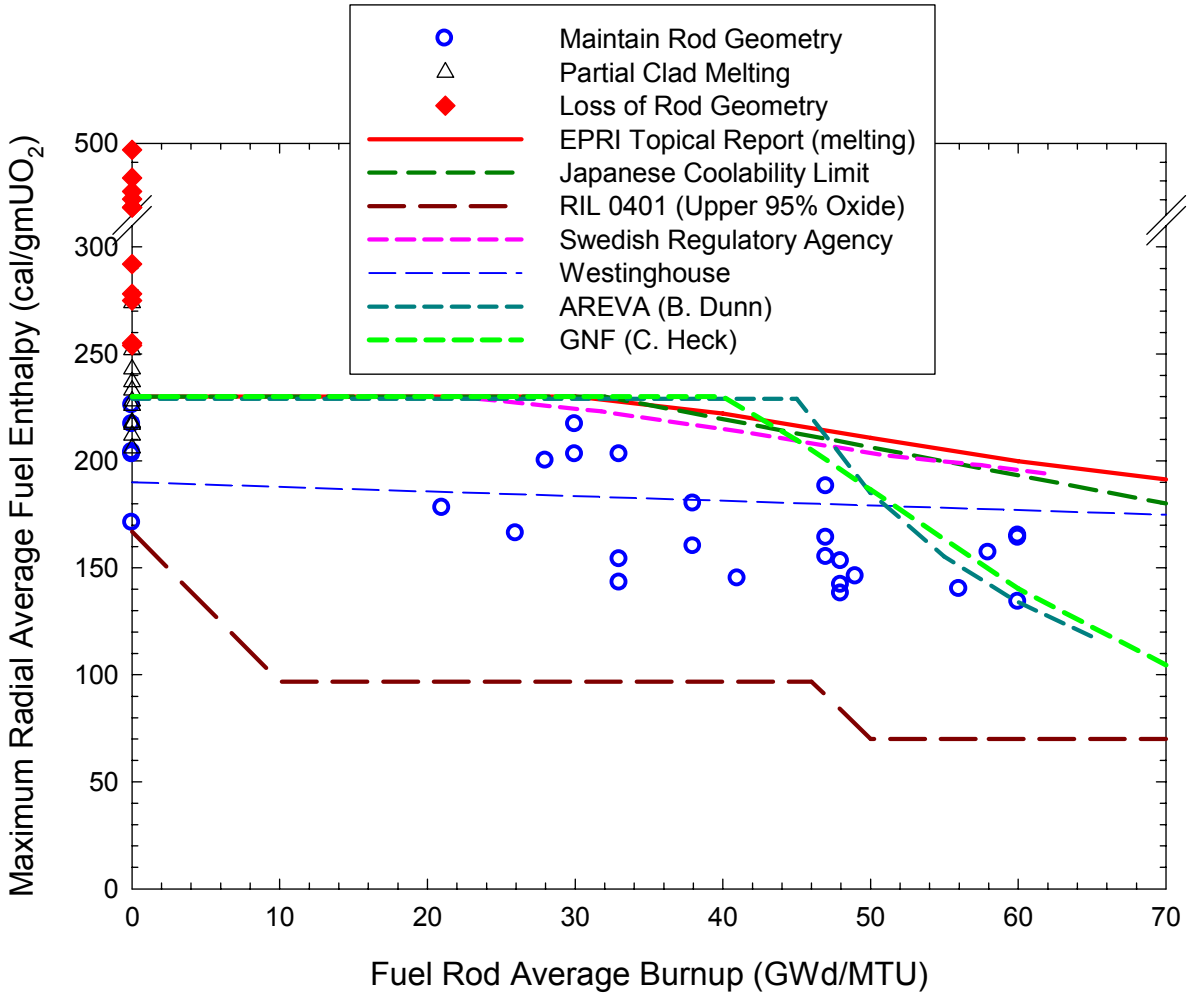
- Separate coolability and failure limits are justified
  - Interim coolability limits can be determined without specific CABRI and NSRR high enthalpy/high burnup tests
  - Data from hot particle-coolant interaction tests support separate failure and coolablity limits
  - Overly conservative limit at high burnup results in limiting max enthalpy for all assemblies

Industry Concepts for PWR Failure Threshold



100 micron limit

Industry Concepts for Coolability Limit



Summary

- Failure threshold
  - We will show alternative treatments of uncertainties that can lead to acceptable interim criteria
  - This would support continued flexibility in fuel design
  - For BWRs need to address pulse shape differences at cold conditions
- Coolability limit
  - Separating the cladding failure threshold and core coolability limit is appropriate for Condition IV accidents
  - We will show alternative approaches based on physical data and mechanisms that lead to higher and more flexible criteria that assures public safety