



AREVA

The Framatome Perspective on Embrittlement Testing Results

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LOCA Criteria Should Be Based on Substantiated Theory Not Hypothesis

A Quick History of Testing and Interpretations

- » ***Basis for Rule – Strength or Ductility***
 - » ***Ductility has merit but does not relate to cladding mission***
 - » ***Strength or Toughness relates to maintaining geometry***
- » ***Concentration on Quench Tests – 1970s to mid 1990s***
- » ***Argonne Tests mid 1970s – Strength, Ductility, and Quench***
- » ***NRC Position on BELOCA – Quench and Impact Testing Sufficient***
- » ***French Tests mid 1990s – Corrosion Layer not Protective***
- » ***NRC Position on Corrosion Layer – Late 1990s***
 - » ***Include Corrosion Layer in 50.46 Compliance***
- » ***Initiation of Argonne LOCA Program – Late 1990s***
 - » ***Fuel Clad Bonding would Limit Strain & Possibly Protective***

A Quick History of Testing and Interpretations

- » ***M5 Licensing – Licensing Based on Quench Tests***
- » ***NRC and Bohmert Tests – All Niobium Alloys Suspect***
 - » ***Refuted by 5 Separate Testing Facilities***
 - » ***Differences in Performance - Surface Preparation, Impurities***
- » ***Limerick Tests – Bonding not Protective, Does not Reduce Strain***
- » ***Framatome Zr-4 Tests – Hydrogen Strongly Enhances Embrittlement***
- » ***NRC – Based on Pre-Hydrating Data – Revised Criteria may be needed***
- » ***HBR Results – May Indicate Corrosion Layer Protective***
 - » ***Argues Against Criteria revision***

What Should We Learn From This History

- » ***LOCA and Post LOCA Cladding Performance (Embrittlement) is Complex***
- » ***Recent Research has Not Clarified Embrittlement Mechanisms***
- » ***Expert Opinion and Hypothesis has Not Been Substantiated by Testing***
- » ***Criteria Change or Reinterpretation***
 - » ***Should Be Based on a Comprehensive Substantiated Theory***
 - » ***Should Be ROBUST in Predicting Cladding Degradation***
- » ***More Basic Research Required***

As We Stand Today

- » Hydrogen Embrittles Non-Irradiated Cladding for LOCA Relevant Transients (DEZIROX, Argonne tests)***
- » Irradiated Cladding with Substantial Hydrogen May Not Embrittle Excessively for LOCA Relevant Transients (HBR tests)***
- » Irradiated and Non-Irradiated (Pre-hydrided) Cladding Survives Quench for LOCA Relevant Transients (TAGCIR, CINOG)***

Required Actions

- » Maintain Current NRC Criteria and Interpretation for Near Term***
- » Remove Artificial Factors Constraining the Testing Programs***
- » Research Should Envelop Basic Information Requirements***
 - » Potential Future Licensing Environment***
 - » Additional Advanced Claddings***
- » Once Clear Proceed with Revision of Criteria if Required***