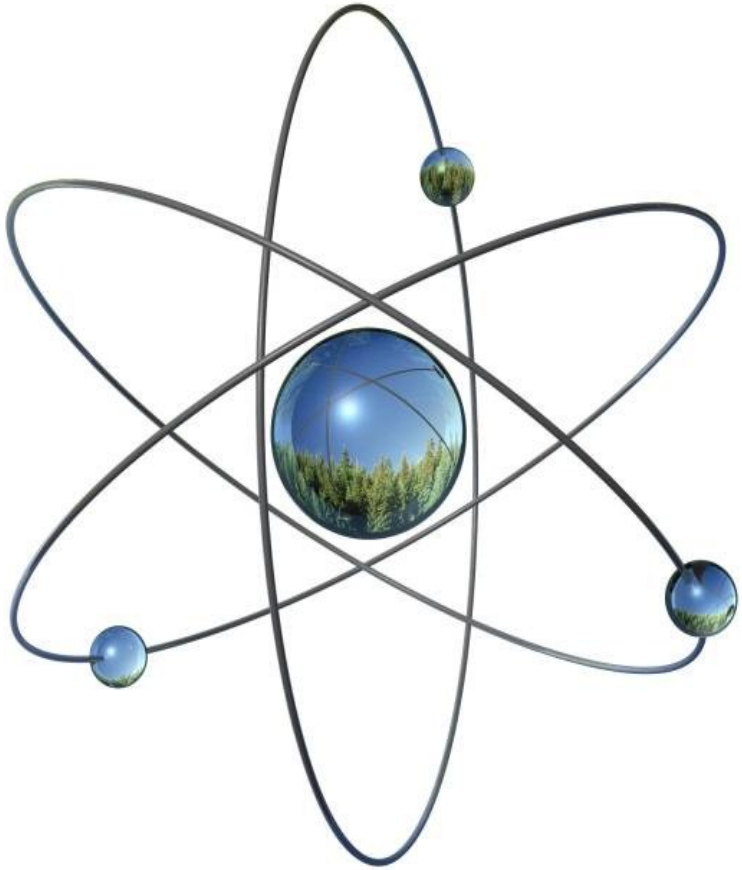
GE Hitachi Nuclear Energy



10 CFR 50.46c Public Meeting
DG-1261 and 1263 on Breakaway Oxidation

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Rockville, MD

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GEH/GNF perspective on DGs

DGs contain much prescriptive details; can improve through elimination of inconsistencies, impracticalities and unnecessary restrictions

Focus here on recommendations related to breakaway oxidation (rule, DGs 1261 and 1263)

Some issues mentioned in April public meeting

(e.g. ±10% CP, water quality)

PQD issues (1262 and 1263)

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Outline

Breakaway Oxidation Risk

Known Key Factors Affecting Onset of Breakaway Oxidation:

- Scratches
- Surface contaminant
- Source material type (Zr extraction)

Breakaway Oxidation Testing

Analytical limit

Recommendations (related to breakaway oxidation)

H model and defining transition ECR (DG 1263 related to PQD)

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Breakaway Oxidation Risk - Scratches

Small impact

On the order of 200 seconds

Discussed in NUREG 6967

- The results suggest that the breakaway oxidation time could be ≈200 s less at ≈1000ºC for fuel rods clad in scratched HBR-type Zry-4 at the beginning of reactor operation.
- For the scratched ZIRLO….. Again, the scratch appears to reduce the breakaway oxidation time by ≈200 s relative to smooth cladding.

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Breakaway Oxidation Risk – Surface F

Strong impact

Fluorine as contaminant on final cladding surface left over from etch/pickle process (used on E110)

Contaminant removable by polishing or machining *[NUREG 6967]*

Readily mitigated by avoiding pickled or as-etched as final surface treatment, using, for example, belt polishing

Currently, all U.S. vendors provide Zr-alloy fuel rod cladding for reload batch applications in belt-polished condition

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Breakaway Oxidation Risk – Zr extraction

Strong impact

Consensus understanding: Related to electrolytic extraction process and associated F pickup *[NUREG-6967, NUREG-IA0211, Chung NET (2005), OECD –NEA 6846 (2009)]*

Direct E110 (electrolytic, higher F) vs E110G (Kroll, lower F) comparison *[NUREG-IA0211, Hozer ASTM 2013]*

Mitigation by avoiding use of electrolytic process for Zr extraction

Currently, all U.S. vendors use Kroll processed Zr

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Breakaway Oxidation Risk

Low risk of breakaway oxidation in modern cladding

Testing required per proposed 10 CFR 50.46c

Recommend:

- Leverage vendor QA program per 10 CFR Appendix B to Part 50 and 10 CFR Part 21; QA program qualifying cladding fabrication process includes testing and ensures no use of electrolytic Zr or as-etched cladding finish
- Leave out test frequency from rule (m.3)

Vendor variants in detail of QA testing implementation and reporting of compliance

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Breakaway Oxidation and Testing

- ***Breakaway*** *Oxidation* – Acceleration (breakaway) of oxidation at higher rate than ideal parabolic kinetics.
- Oxidation results in weight gain and oxide thickness increase.
- Timing of onset of accelerated or breakaway oxidation affected by known factors (Zr extraction, surface contaminants, scratches)
- Consequences – Discoloration, spalling and Hydrogen pickup
- Observable: weight gain, oxide thickness, visual, Hydrogen

Recommend:

  - Weight gain can be used to establish onset of breakaway (in addition to H and visual) with multiple or on-line thermogravimetric (TG) measurements.

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Breakaway Oxidation Testing

- Steam purge conditions in DG-1261 may not be applicable to TG instruments
- Cooling rate is not important using TG instruments
- Sample size is not a key factor for breakaway oxidation
  [Amaya/JAEA; Nagase/JAERI; Aomi/NFD; Baek/KAERI, Hozer/KFKI use between 5 – 10 mm length cladding samples]

Recommend:

- Provide provision for steam purge conditions relevant to TG instruments
- Sample size less than 25 mm can be used

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Breakaway Oxidation Test Replicates

DG 1261 requires each test to have 5 replicates

Analytical limit expected to be set at less time than breakaway time determined from scoping test

Routine test time expected to be at or less than at time for analytical limit

Recommend:

- Reduce replicate requirement to 2 or 3 (ideally be based on margin between test time and breakaway time)

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Analytical limit

Inconsistency in "temperature susceptible" vs. 650°C:

- Proposed rule g.1.iii *"total accumulated time ……to remain above a **temperature at which the zirconium-alloy has been shown to be susceptible** to breakaway oxidation ……."*
- 1263 B Methodology for Establishing Analytical Limits *"time spent at **temperatures >650 °C** in establishing the analytical limit"* appears to be based on L-S data and lack of hydrogen data between 650 °C and 800 °C in NUREG-IA0211. EPRI presentation from April workshop showed low H in modern Zry4 cladding after 7000s testing at 800°C.
- 1263 B Applying Analytical Limits *"… is predicted to remain above a **temperature at which the zirconium alloy has been shown to be susceptible** …"*
- 1263 C.5.c *"total accumulated time the cladding may remain **above 650 °C**"*

Recommend:

- Use "susceptible temperature" consistent with proposed rule
- Both time and temperature obtained using DG 1261 be used to define analytical limit in 1263

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Summary of Recommendations – Breakaway Oxidation

Proposed 10 CFR 50.46c

- Leverage vendor QA program to address testing and ensure no use of electrolytic Zr or as-etched cladding finish
- Leave out test frequency from rule (m.3)

DG 1261

- Weight gain can be used to establish onset of breakaway (in addition to H and visual) with multiple or on-line (TG) measurements.
- Provide provision for steam purge conditions relevant to TG instruments
- Sample size less than 25 mm can be used
- Reduce replicate requirement

DG 1263 on analytical limit for breakaway oxidation

- Use “susceptible temperature” consistent with proposed rule
- Both time and temperature obtained using DG 1261 be used to define analytical limit

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DG 1263 - H model related to PQD

In 1263 B Applying Analytical Limits related to H model:

- Paragraph on Qualification of H Pickup Models *"quantify axial, radial, and circumferential variability"* appears to be excessively detailed in light of last paragraph on Accounting for Uncertainty…. *"based on predicted peak circumferential average hydrogen content for the individual rod"*.
- Axial location for peak circumferential average hydrogen may not coincide with location with highest transient oxidation.

Recommend:

- Provide consistent wording to the effect that that models address circumferentially averaged H

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DG 1263 - Transition ECR

On defining transition ECR as function of hydrogen

- Scatter plot of post-test hydrogen versus ECR is a practical and simpler way to define the transition ECR

Recommend:

- Guide to provide provision for other methods to defining transition ECR

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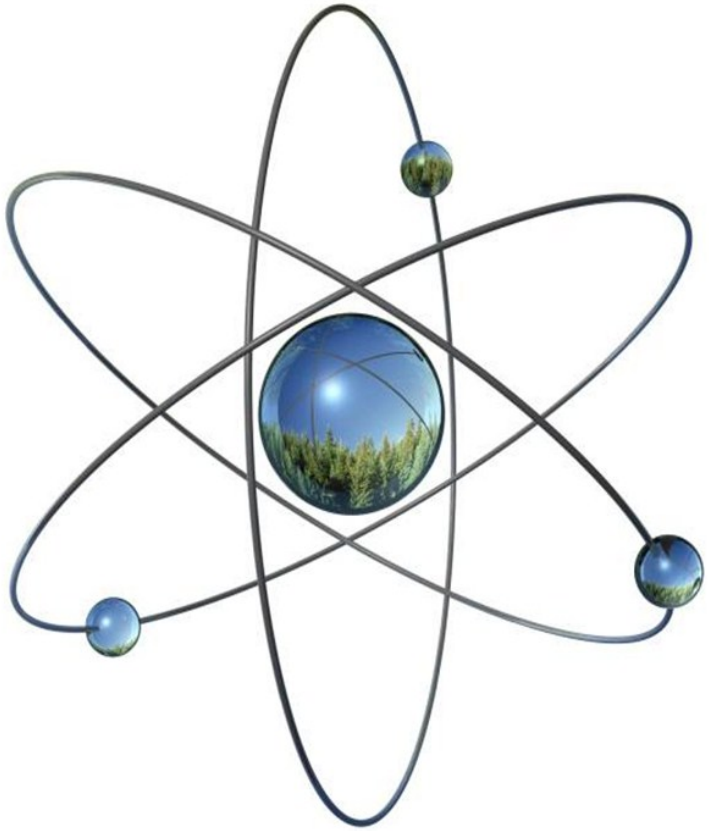

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