Interim Staff Guidance No. 11, Revision 2

Kim Gruss
Sr. Materials Engineer
Spent Fuel Project Office

Presentation Overview

- Background
- Lessons Learned
- ISG-11, Revision 2, Acceptance Criteria
- Implementation Issues

Background

- ISG-11, Rev. 0 Issued in May 1999
  - Limited acceptance criteria
- HBF Issue Identified as High Priority in December 1999
- ISG-11, Rev. 1 Issued in May 2000
  - Uncertainty in Materials Property Data
  - Prescriptive Acceptance Criteria
- Received Numerous Applications, Amendments, Topical Reports
- ISG-11, Rev. 2 Issued in July 2002

Lessons Learned

- Extensive fuel oxide thickness measurements required
- Licensees are unable to load:
  - HBF w/ oxide greater than 80 microns as intact
  - Non-Zircaloy clad fuel (Zirlo, M5, etc.)
  - Casks with all HBF assemblies
- Review of topical reports and amendments required significant licensee and staff resources

Basis for Revising ISG

- New data on properties and characteristics of high burnup fuel
- Public meetings on high burnup fuel
- Industry, vendor, and licensee topical reports
- Staff analyses of creep, mechanical properties, consequences of fuel failures

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Cladding Considerations for the Storage and Transportation of Spent Fuel

ADAMS Accession No. ML022110372

Changes to ISG-11

- Definition for intact and potentially damaged high burnup fuel (oxide thickness limits) removed
- Creep strain limit of 1% removed
- Confinement analysis assumption of leaky rods removed
- Temperature limit to minimize creep rupture and hydride reorientation added
- Transportation reviews will be reviewed on a case-by-case basis

Applicability

- All spent fuel burnup levels that are licensed by NRR
- All cladding materials licensed by NRR

Part 72 Regulatory Requirements

- Ensure doses are controlled
- Maintain subcriticality
- Ensure confinement of spent fuel
- No gross rupture of cladding or adequately confine fuel during storage
- Maintain retrievability of spent fuel

Acceptance Criteria (1)

- Normal (long-term) storage conditions
  - Cladding temperature limits of 400°C
  - Applicability:
    - All spent fuel regardless of burnup level

Acceptance Criteria (2)

- Fuel loading (short-term) operations (e.g., drying and backfilling)
  - Cladding temperature of 400°C
  - Applicability:
    - All spent fuel regardless of burnup level

Acceptance Criteria (3)

- Fuel loading (short-term) operations (cont'd)
  - Minimize repeated thermal cycling - temperature differences less than 65°C
    - Intent of criteria – prevent use of a drying/loading procedure that could inadvertently enhance hydride reorientation
    - Repeated thermal cycling – pertains only to the time during fuel loading operations and transfer of the cask to the pad
    - Basis for ?65°C – change in temperature (upon cooling) that causes precipitation of hydrides (based on unirradiated Zry-4 plate) to occur

Acceptance Criteria (4)

- Basis for 400°C limits
  - Minimizes creep rupture
    - Creep capacity of Surry low burnup fuel is > 5% after 15 years of storage (ANL experiments)
    - Uniform circumferential creep deformation up to 5%
    - Over storage period, cladding temperatures, pressures and hoop stresses decrease (creep deformation rate constantly decreasing)
    - Cladding failure due to creep, if it occurs, will not result in gross rupture

Acceptance Criteria (5)

- Justification for 400°C limits (cont'd)
  - Minimizes hydride reorientation
    - Threshold stress for hydride reorientation is 90-145 MPa
    - For high burnup fuel (larger fission gas release), 400°C limits hoop stress
    - For low burnup fuel (low fission gas release), stresses well below 90 MPa

Acceptance Criteria (6)

- Accident conditions of storage
  - Cladding temperature of 570°C
  - Applicability:
    - Accidents leading to high cladding temperatures (e.g., fires, blocked vents)
- Basis for temperature limit
  - No creep rupture observed in low burnup fuel for 30 days at 570°C

Acceptance Criteria (7)

- Confinement reviews
  - Release fractions from cladding should be consistent with ISG-5
  - No assumption of any "leaky" rods (old requirement of ISG-11, Rev. 1)

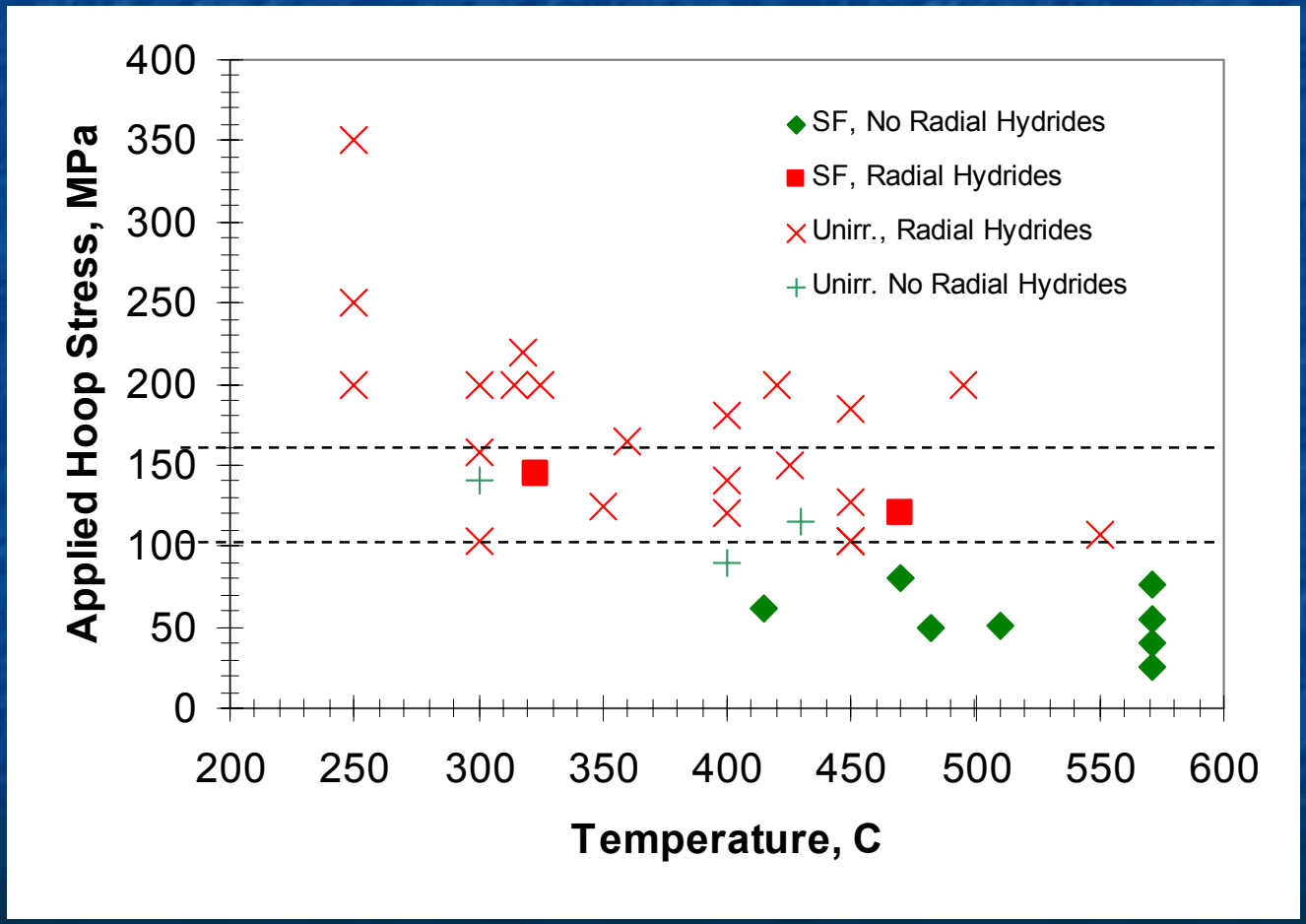
Implementation Issues

- Does the 400°C short-term fuel loading temperature limit apply to previously certified cask designs?
  - No. Staff backfit analysis demonstrated no impact on the safety of storage cask designs which utilized 570°C for fuel loading operations of low burnup fuel (< 45 GWd/MTU, hoop stresses < 90 MPa).

Backup Slides

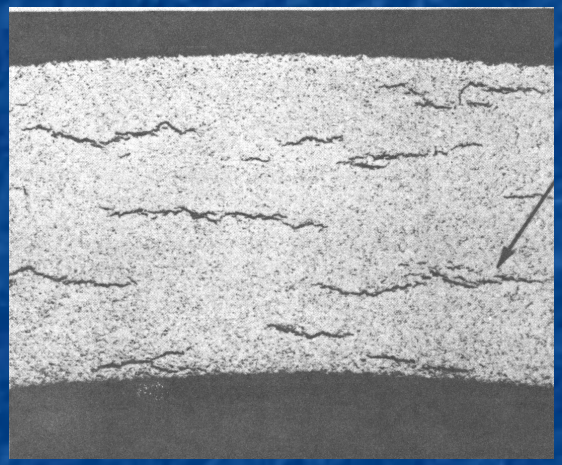
Hydride Reorientation (1)

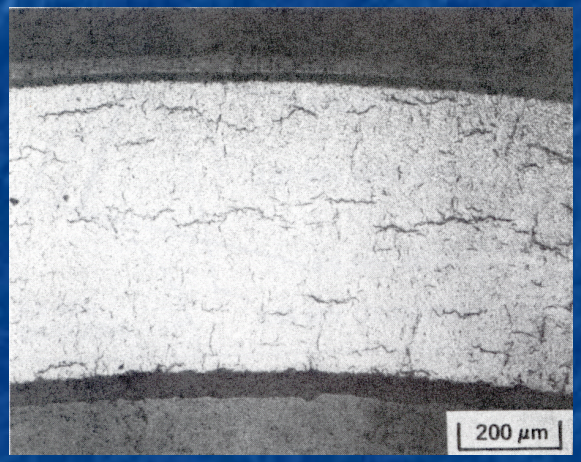
Threshold Stress for Hydride Reorientation to Occur = 90-145 MPa

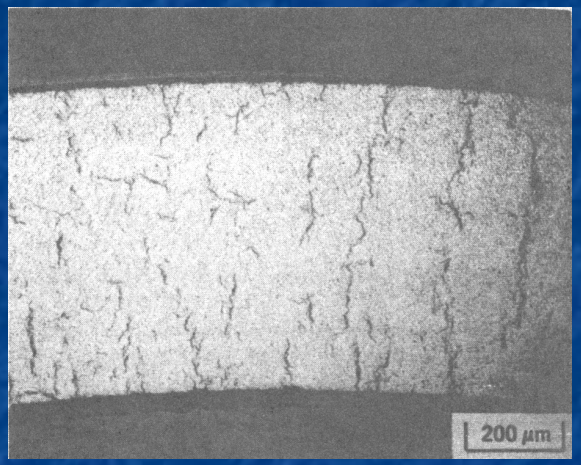


Hydride Reorientation (2)

Low Hoop Stress f(Temp, H conc, etc.) **High Hoop Stress**







Circumferential Hydrides in Irradiated Zircaloy Cladding

Mixed Hydrides In Irradiated Zircaloy Cladding

Radial Hydrides In Irradiated Zircaloy Cladding

Photographs from Nuclear Technology, v. 67 (Oct. 1982) p. 107.

Thermal Cycling (1)

- Effects of cycling on reorientation are complex function of many parameters – initial temperature, change in temperature, number of cycles, stress, hydrogen concentration, material defects, etc.
- Irradiation, cold working, annealing affect solubility of H in Zircaloy (involves defect trapping/release of H)
- Amount of H in solution, amount available to form radial hydrides and hoop stress determines extent of circumferential/radial hydride network
- Increasing number of cycles can significantly enhance formation and growth of radial hydrides

Thermal Cycling (2)

T, C	C(H,d)	C(H,p)	delta T for ppt	Amt H (ppm) available from 400C
400	210	339	65	0
375	168	285	66	0
350	132	236	66	0
335	114	209	66	1
310	86	169	66	41
300	77	154	66	56
285	64	134	66	76
280	60	127	66	83
250	40	93	66	117
220	26	65	65	145

Certification Options for Transportation Cask Approvals

Earl Easton, Chief
Technical Review Section A
Spent Fuel Project Office

Transportation of Spent Fuel

- Type B package certification
  - Adequate cladding materials properties
  - Bounding criticality models
- Special arrangements
- Exceptions, § 71.55(c)
- Part 71 rulemaking – moderator exclusion for dual purpose casks

Future Plans

Plans for Revising ISG-11

- Revision 3
  - Revise temperature limit for short-term fuel loading operations for low burnup fuel (<45 GWd/MTU)
  - Add staff backfit analysis which supports temperature limit of 570°C for low burnup fuel only (demonstrate low hoop stresses)
- Revision 4
  - Add criteria to address transportation of spent fuel

NEI Responses to Outstanding Requests for Additional Information

- Open Items
  - Question B4 and B6 – quantify % of fuel pin failures, safety margins in cask design
    - Staff would like to see industry analyze response of high burnup fuel cladding to transportation accidents using properties of high burnup fuel
    - Response will be used to address criticality safety of transportation casks
    - Cask design margins (shielding, thermal, etc.) should also be evaluated

NEI Responses to Outstanding Requests for Additional Information

- Open Items (cont'd)
  - Question B5
    - Staff agrees with NEI suggestion to defer response until after the dry storage PRA's are completed.