Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

Fuel Material Properties and Dry Storage

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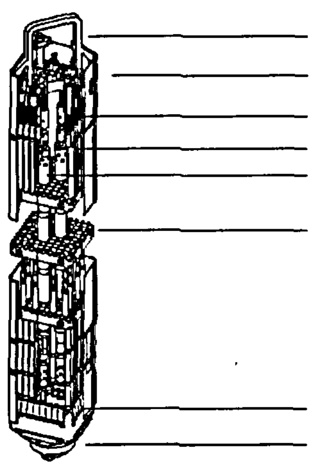
Typical BWR Fuel Assembly



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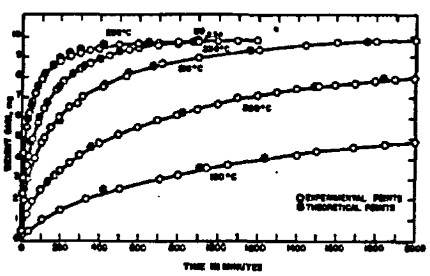
Fuel Assembly Materials

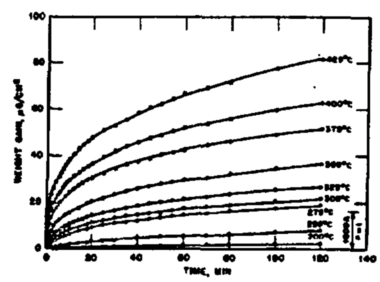
Component	Material	Principal Storage Issues
Upper tie plate	Cast austenitic stainless steel	None
Fuel rod expansion spring	Ni-Cr-Fe-Ti alloy	None
Fuel rod	Cladding: Zr-2 tube with or without Zr ID liner Fuel: UO_2, $(U,Gd)O_2$ Retainer Springs: Austenitic Stainless Steel or Ni-	Structural integrity of Zry at high burnup Effects of time, temperature and stress on cladding integrity Oxidation of Zr-2 and fuel materials
Water rod	Zr-2	Structural integrity Oxidation of Zr-2 (Water rod expected to have minimal effect on fuel storage)
Spacer	Zr-2 or Zr-4 structure with Ni-based alloy springs All Ni-based alloy	Structural integrity Oxidation of Zry (Spacer expected to have minimal effect on fuel storage)
Finger spring	Ni-Cr-Fe-Ti alloy	None
Lower tie plate	Cast austenitic stainless steel	None
Channel	Zr-2 or Zr-4	Oxidation of Zry (Channel expected to have minimal effect on fuel storage)

Principal concerns center on fuel rod integrity under conditions of drying and storage

Oxidation



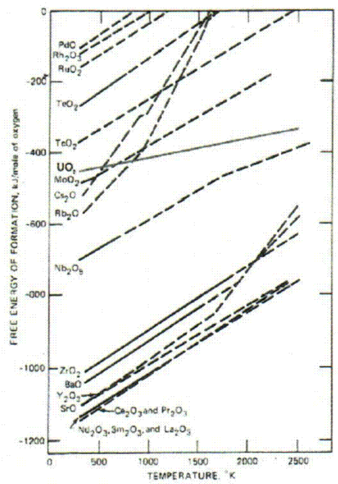
(data after J. Bell)



(data after B. Lustman and F. Kerze)

- Fuel pellets and Zircaloy components oxidize rapidly in air
- Rate of oxidation increases with temperature

Oxidation - Continued



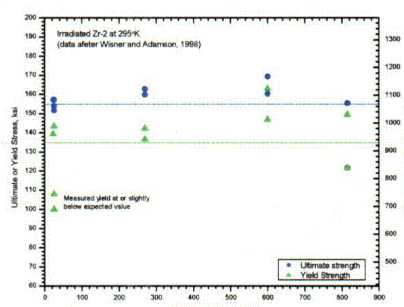
(data after D. Olander)

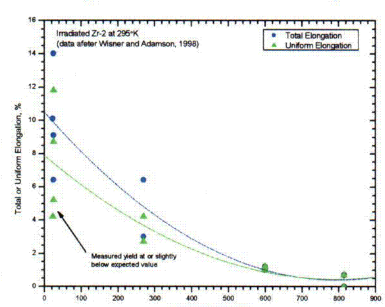
- Zry components will oxidize preferentially relative to fuel pellets
- Zry components will getter air during drying phase
- Continued air leakage into a cask presents the possibility of structural decomposition of the cladding followed by similar oxidation and decomposition of the fuel pellets
- Protection against oxidation is assumed to come from the cask design, cask loading and long-term monitoring practices

(Limited options relative to fuel materials or designs in this area)

Hydriding

Effect of Hydrogen on Zr-2 Tensile Properties at Room Temperature

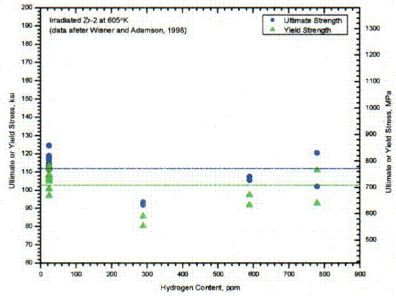


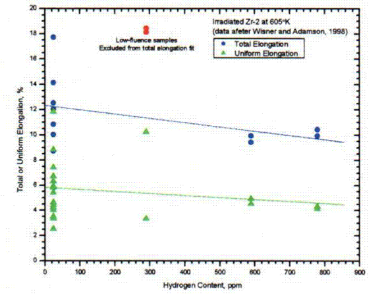


- Strength at RT remains high through ~600 ppm hydrogen
- Ductility decreases with hydrogen concentration, becoming small at hydrogen concentrations >600 ppm
- NB: Randomly oriented hydrides and short-term loading

Hydriding

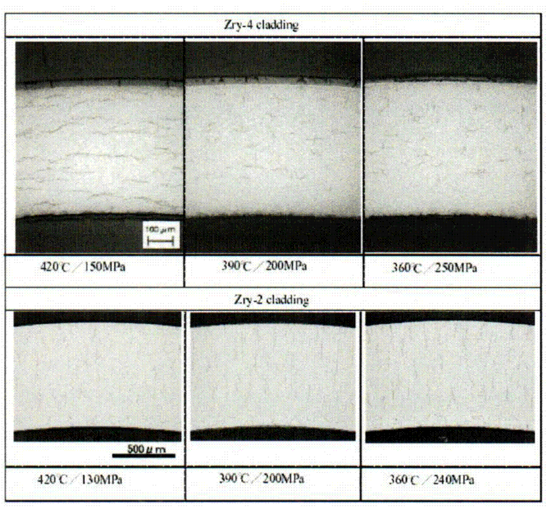
Effect of Hydrogen on Zr-2
Tensile Properties at 332° C





- Strength and ductility at 330°C remain high through hydrogen concentration of ~800 ppm
- NB: Randomly oriented hydrides and short-term loading

Hydride Reorientation



⇒ Reorientation stress ≥ 110 MPa (16 ksi) for SRA Zr-4

⇒ Reorientation stress < 110 MPa (16 ksi) for RXA Zr-2

(data and assessment after Ito, et al.)

Planned and Potential Work

Fuel Rod and Materials at Exposures ≥ Current EOL

- Corrosion and hydrogen pickup
  - > Oxide thickness, hydrogen concentration
  - > Hydride morphology
- Mechanical properties
  - > Hardness
  - > Curvilinear axial and plane strain tensile tests
  - > Expanding mandrel tests
  - > (Burst tests)
  - > (Hydride reorientation tests)
- Fuel rod and fuel materials characterization
  - > Burnup and isotopic composition
  - > Fission gas release
  - > Cladding deformation during operation (profilometry, length change)
  - > Cladding structure (optical and electron microscopy)

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GNF BWR Fuel Performance and Characterization

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Agenda

- Fuel Rod Design Description
- Fuel Reliability Performance
- Fuel Rod Failure Mechanisms
- Recent and Ongoing High Exposure Fuel Performance Characterizations

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Going Forward

- Some characterization information available today
- More characterization may be desirable based on NRC identified interests
- Opportunity exists with GNF high burnup cladding currently available at GE VNC hotcells
  - Additional planned high burnup cladding retrieval provides additional opportunity
- GNF is open to cooperative program with NRC to provide further characterization

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