<u>Radiation Damage - Zr</u>

(See D. O. Northwood, Atomic Energy Review, Vol. 15, No. 4, p. 547, 1977)

• ***Note that the operating temperature for Zircaloy in LWR's is 100 - 350°C but mainly 300 to 350 °C***

• ***Most typical damage structure is a high density of dislocation loops (20 - 100 Å in diameter)***

<u>Neutron Fluence Effects on Zircaloy - II</u>

1.) no damage observed below 2 x 10^{19} n cm^{-2} (E> 1 MeV)

2.) Density of loops decreases with increasing n fluence

3.) Loop size increases with increasing fluence

4.) Saturation in visible defects at ≈ 1 x 10^{21} n cm^{-2} (E >1 MeV)

(Figure 7-23)

<u>Temperature Effects</u>

• **Above ≈ 500 °C, no visible damage found**

• At T > 400 °C, mainly vacancy loops

• At T< 400 °C, mainly interstitial loops

• Voids only found in ion bombarded samples when gas atoms are preinjected

Alloying

Increasing alloying elements in solid solution, decreases loop size and increases loop density

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For the effects of microstructure and stress, see Northwood

Recent Information From Dr. Ron B. Adamson
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• Performance to date of BWR and PWR fuel

@ 40,000 MWd/MT (8×10^{21} n/cm^2, E>1 MeV)

only 1 failure in 100,000 rods

• The use of Zr sleeves has solved the PCI prob. (10 years ago the major mode

of fuel failure was Pellet Clad Interaction (PCI))

- **Crud Induced Localized Corrosion (CILC) definitely linked to Cu in BWR water. Many utilities have replaced copper based condenser tubes with stainless steel or Ti tubes.**

- **<u>Near term goal for BWR's and PWR's</u>**

  - **45,000 MWd/MT for BWR's**
  - **60,000 MWd/MT for PWR's**

  - **only 1 failure in 1,000,000 rods**

- **Irradiation makes $Zr(Cr,Fe)_2$ precipitates amorphous by 1×10^{21} n/cm^2**

- **Radiation Effects**

  - **Fatigue (Fig)**

  - **Growth (Fig)**

  - **Creep (Fig)**

GE Method to Reduce FCI in LWR's - After Adamson

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