# Radiation Damage - Zr

**( 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)***

## Neutron Fluence Effects on Zircaloy - II

**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)**

## Temperature Effects

• **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**

**<u>Alloying</u>**

**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***

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**Recent Information From Dr. Ron B. Adamson**
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**• <u>Performance to date of BWR and PWR fuel</u>**

**@ 40,000 MWd/MT ($8x10^{21}$ 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**

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

- **Radiation Effects**

  - **Fatigue (Fig)**

  - **Growth (Fig)**

  - **Creep (Fig)**