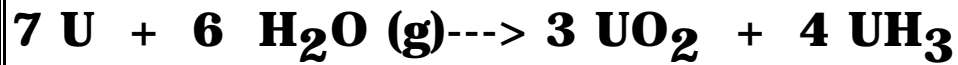
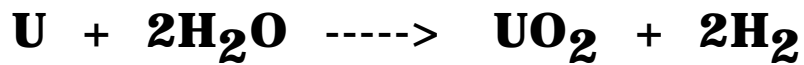


Aqueous Corrosion

150-250°C



600-700°C



Reduction of Corrosion in Water

- **Metastable γ phase** - **U + 7% Mo**
or, **U + 7% Nb**
- **Supersaturated α phase** - **U + 3% Nb**
U + 1.5 % Nb + 5% Zr
U + 3 % Nb + 0.7 Sn
- **Intermetallic Compounds** **U₃Si**

Irradiation Creep

- **Thermal Creep -**

Plastic deformation of a solid at high temperatures while the stresses are below yield strength

- **Irradiation Creep -**

Enhanced thermal creep, usually proportional to fission rate

First Russian Report of Accelerated Creep -

- *English Version $\approx 1.5 - 2$ %*
- *Later Translation ≈ 1.5 to 2*
- *1958 Conference ≈ 1.5 to 2 orders of magnitude*

Growth

1.) First instability to be recognized

- 1955 - 1st UN Conf. on Peaceful Uses of Atomic Energy
- US, USSR, and UK found tremendous variations in the behavior of polycrystalline rods
- Found: (figure)

[010] Elongation
[100] Contraction
[001] No Change

2.) Growth rate at any time depends on the length at that time rather than the initial length.

$$L = L_o e^{Gf}$$

Where

G = growth const.

f = frac. of atoms that have fissioned

$$G = \frac{\ln\left(\frac{L}{L_o}\right)}{f}$$

normally report

$$\frac{\% \text{ Growth}}{\% \text{ Burnup}}$$

G is very temperature dependent (figure)

at 0.2% BU, (1850 MWd/tonne U)

$$\frac{L}{L_0} \approx 2-3 @ 100^\circ\text{C}$$

Texture Effects
(figure)

Elongated Rod (figure)

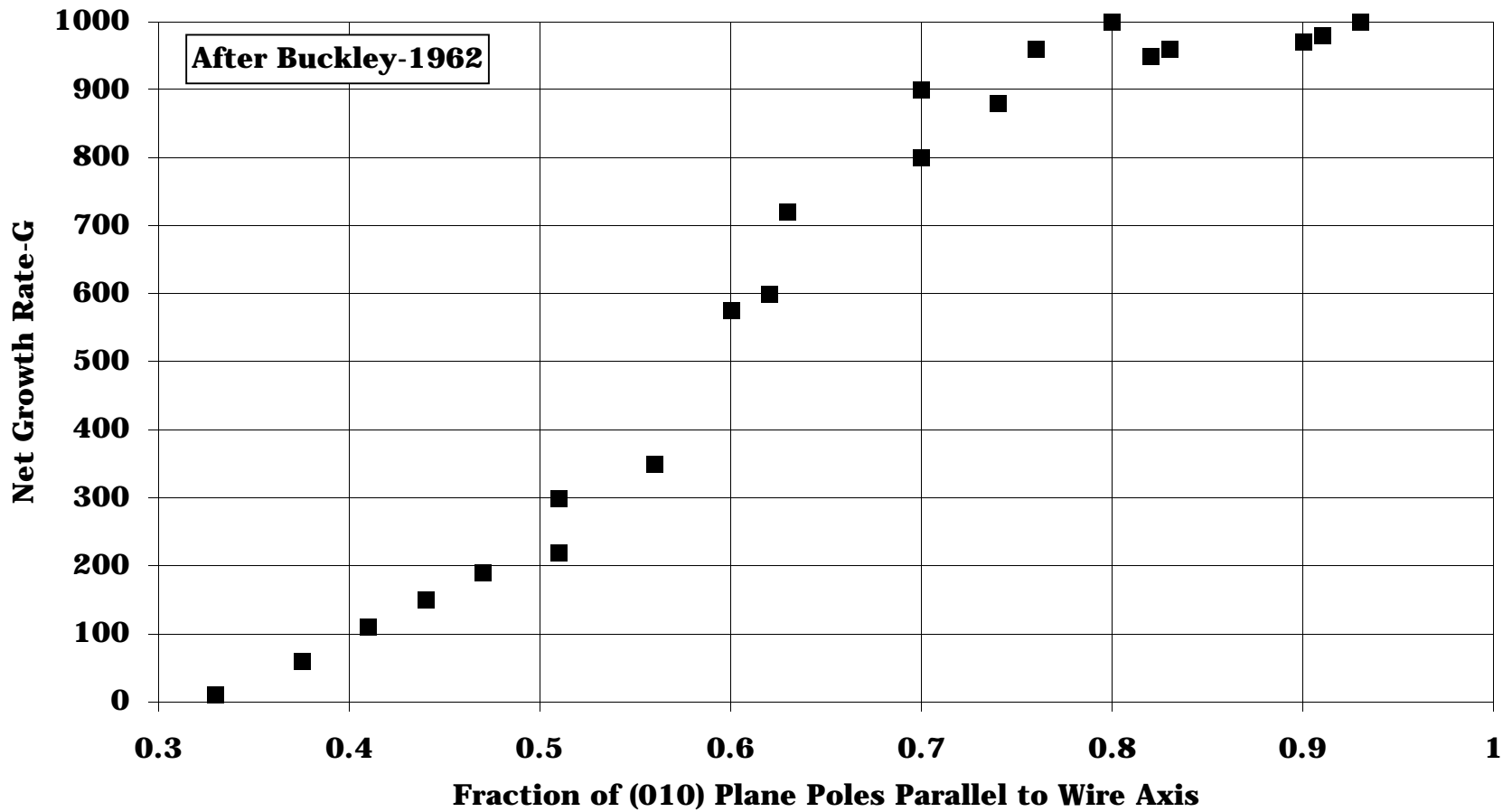
Explanation

- **Fission fragments cause local heating**
 - expansion-100, 001 (attracts vacancies)
 - contraction-010 (attracts interstitials)
- **Defect migration produces**
 - Vacancy loops on {100} planes
(actually on {110})
 - Interstitial loops on {010} planes

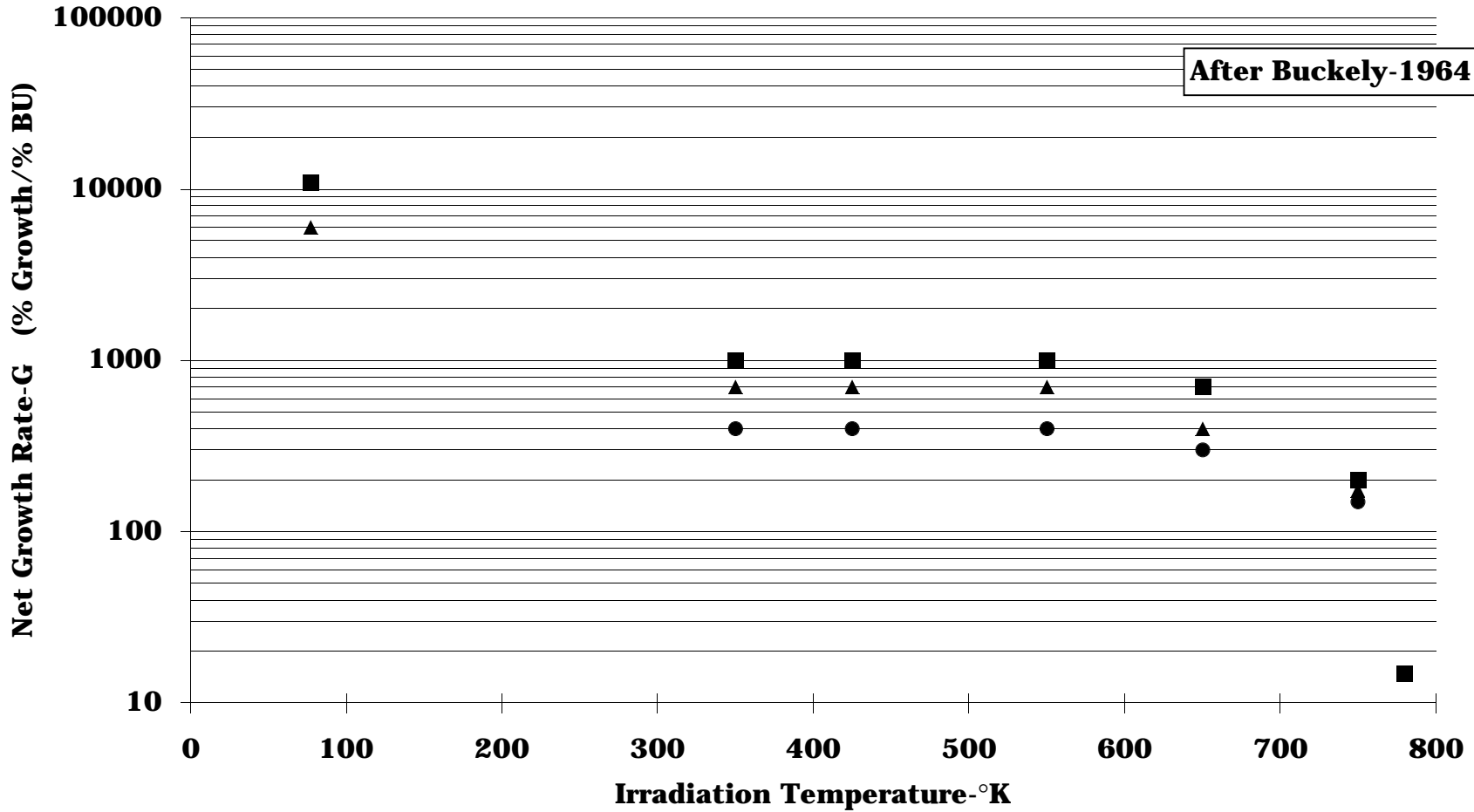
Temperature Effects

- **Low temperatures---> Random Loops
(interstitials)**
- **Moderate Temp.---> Vacancy Loops
(80-350 °C) Aligned**
- **Above 500°C -----> Loops anneal out**

The Net Growth Rate of Polycrystalline U Wires Depends on the Fraction of (010) Pole Planes Parallel to the Wire Axis



The Growth Constant of U is Greatly Reduced at Higher temperatures



Physical Properties of the Six Plutonium Allotropes

Phase	Crystal Lattice	Number of Atoms Per Unit Cell	Transition to Next Higher Phase, °C	Density gm/cm ³	Coeff. of Thermal Expansion x 10 ⁻⁶ per °C	Volume Change on Transformation, %
Alpha	Monoclinic	16	112	19.8	46.4	$\alpha \rightarrow \beta$, 8.9
Beta	Body centered Monoclinic	34	185	17.65	38.4	$\beta \rightarrow \gamma$, 2.4
Gamma	Face centered Orthorhombic	8	316	17.2	34.7 (a=-19.7) (b= 39.5) (c = 83.4)	$\gamma \rightarrow \delta$, 6.7
Delta	fcc	4	451	15.9	-8.8	$\delta \rightarrow \delta'$, -0.4
Delta Prime	body centered tetragonal	2	480	16.0	-116, (a=305) (c= -659)	$\delta' \rightarrow \epsilon$ - 3.0
Epsilon	bcc	2	640	16.51	+36.5	

Swelling

fission-->2 atoms-->3 times U vol.

Early studies found much higher swelling rate

(Figure)

Temperature Dependence

- **350-500 °C - Growth (tearing)**
- **500-600 °C - Aligned pores/Voids**
- **> 600°C - Gas Bubble Swelling**

Al, Mg, and Fe reduce cavitation swelling by reducing grain size and increasing σ_y

Breakaway Swelling *(Figure)*