Realistic High Burnup UO_2 Fuel Response to a LOCA in a PWR

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Objectives

- Compare LBLOCA Transient Response for Lead Fresh and High Burnup Assemblies in Same Core
- Realistic Codes will be Used, but Typical Design Basis Assumptions will be Applied (Worst Single Failure, etc.)
- NRC-Approved Uncertainties in Physical Models and Plant Conditions Applied

Burnup Effects Considered

1. Depletion of Fissionable Isotopes (“Burndown”)
2. Fuel Thermal Conductivity Degradation
3. Fission Gas Release / Rod Internal Pressure
4. Decay Heat Contributors

Analysis Tools

WCOBRA / TRAC – System T / H Response Uncertainties

- Vessel – two fluid, three fields (vapor, continuous liquid, droplets)
- Loops – drift flux

HOTSPOT – Fuel and heat transfer model uncertainties

- 1-D conduction code, uses WC / T boundary conditions (explicit fuel relocation model for burst node)

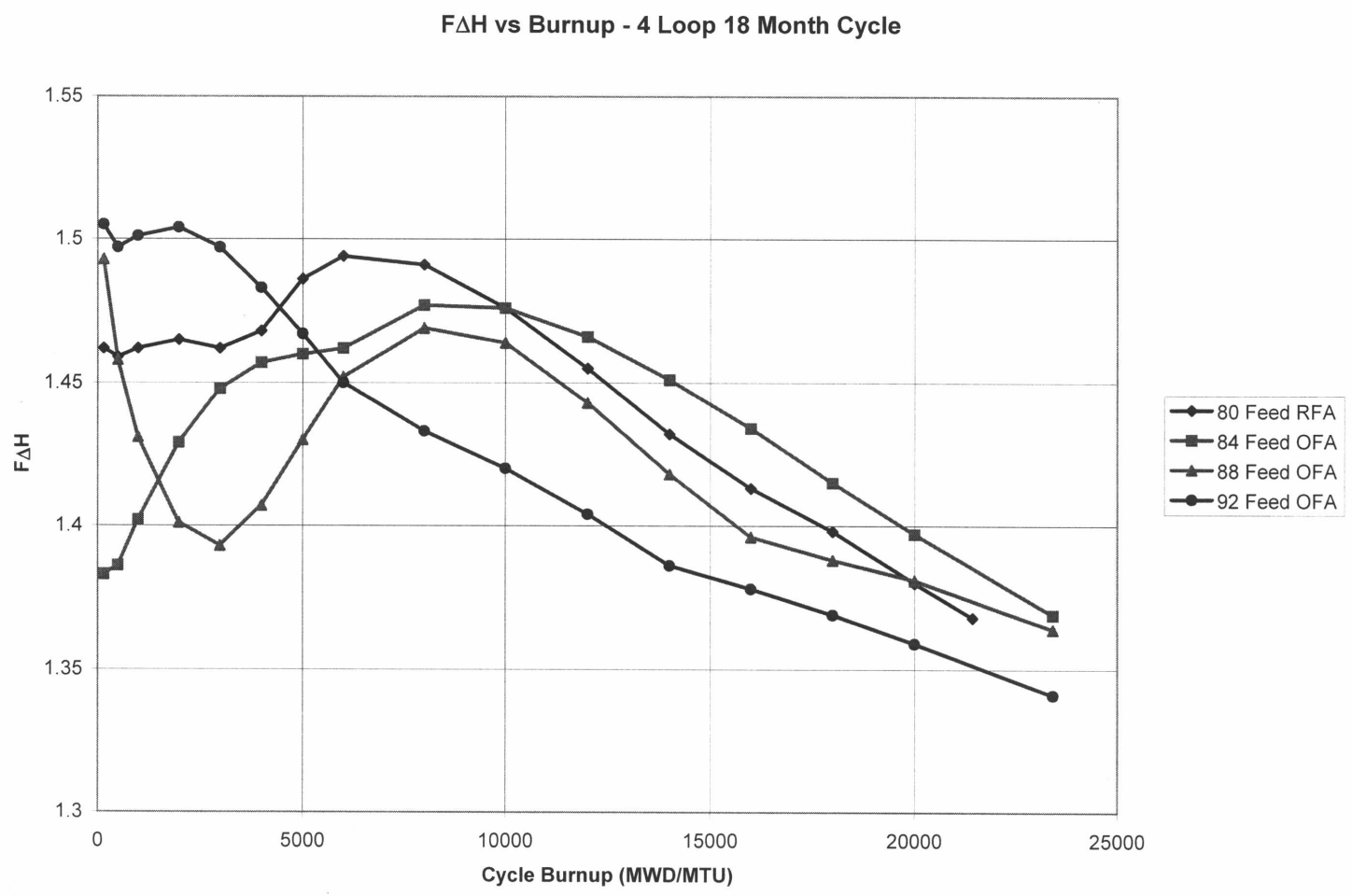
Analysis Method for Fresh Fuel

- Non-Parametric Statistical Method
- Sampling From Uncertainty Distributions for ~40 Parameters for Each of 59 Cases
  - Worst case captures at least 95% of PCT distribution with 95% confidence
- Key WC / T Parameters Include Break Flow (1 ft^2 => DEG), Axial Power Shape, Peaking Factors & Burnup (Stored Energy)
- Key HOTSPOT Parameters Include Fuel Conductivity, Gap Conductance, Heat Transfer to Fluid

Modifications for High Burnup Fuel

- Peaking Factor Reductions (25% at 45 GWD / MTU to 40% at 65 GWD / MTU)
- Thermal Conductivity Degradation (Estimated Using NUREG / CR-6534, FRAPCON-3)
- Fission Gas Constituents, Rod Pressure
- Decay Heat
  => All Other Parameters at Previously Sampled Values

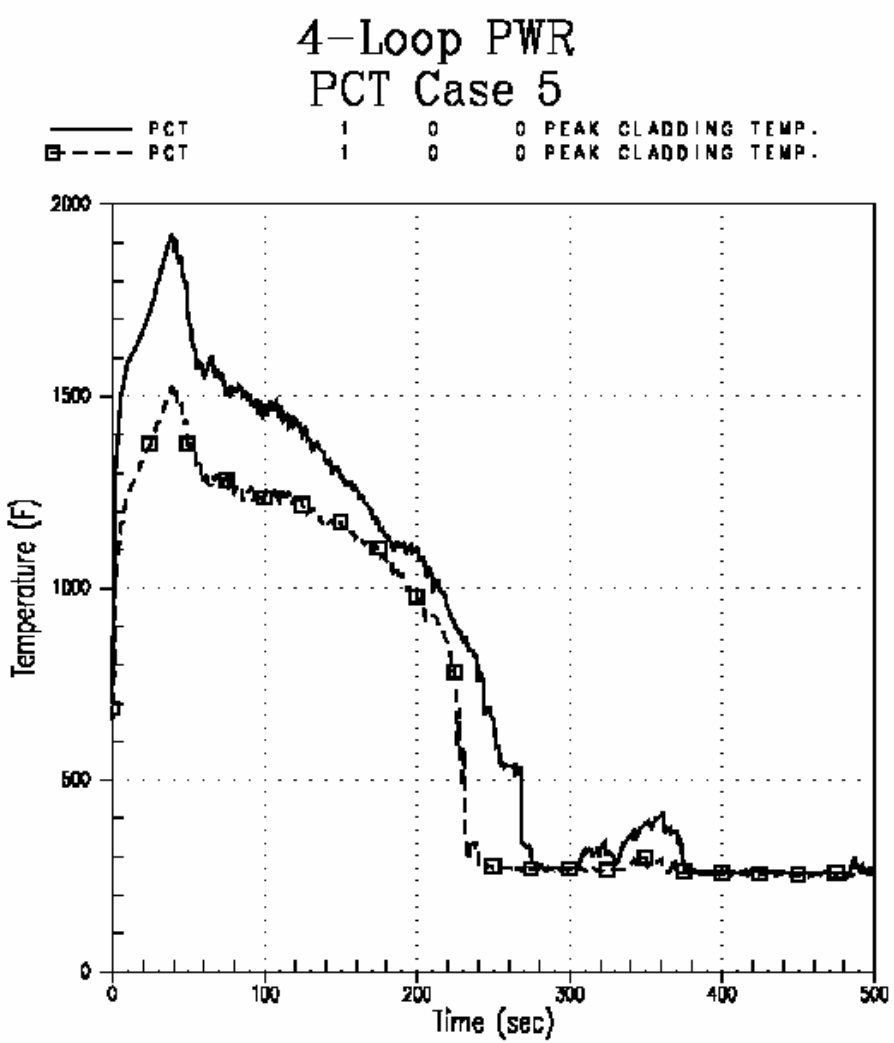
Burndown for Typical Core Designs (Tech Spec Limit = 1.65)

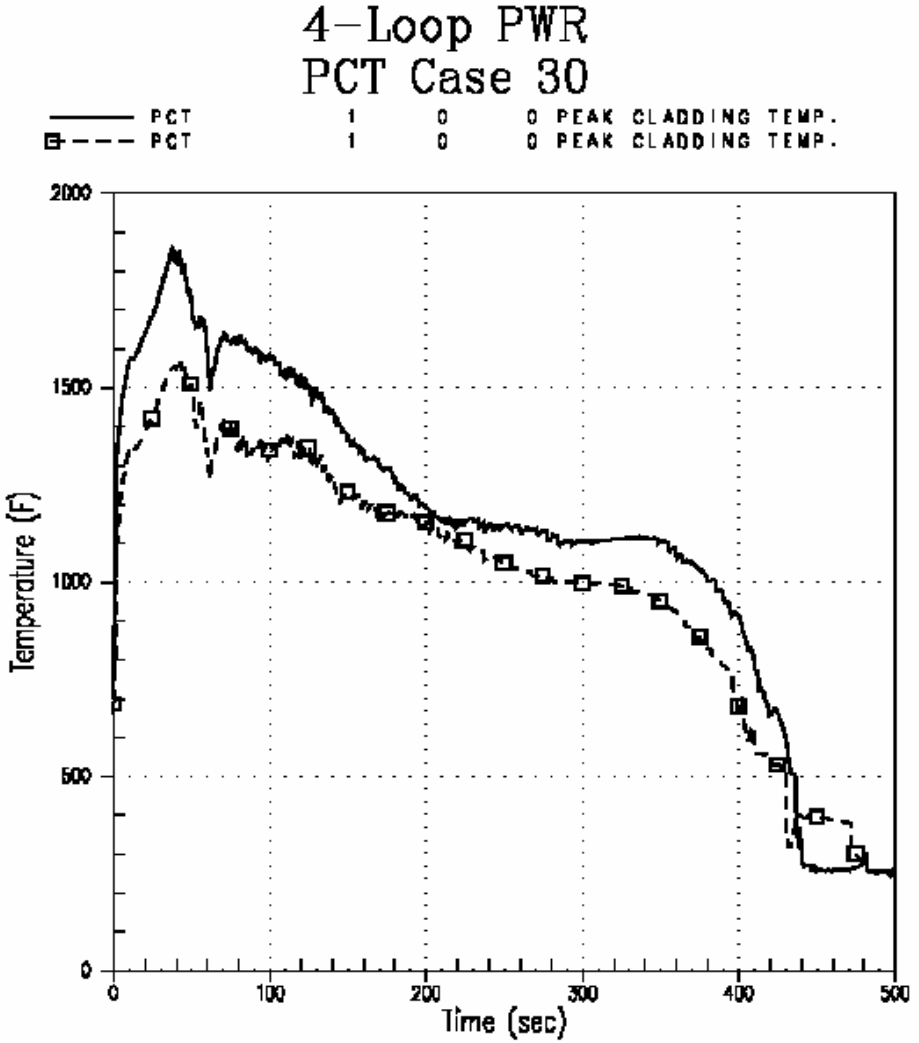


Analysis Results (59 Cases)

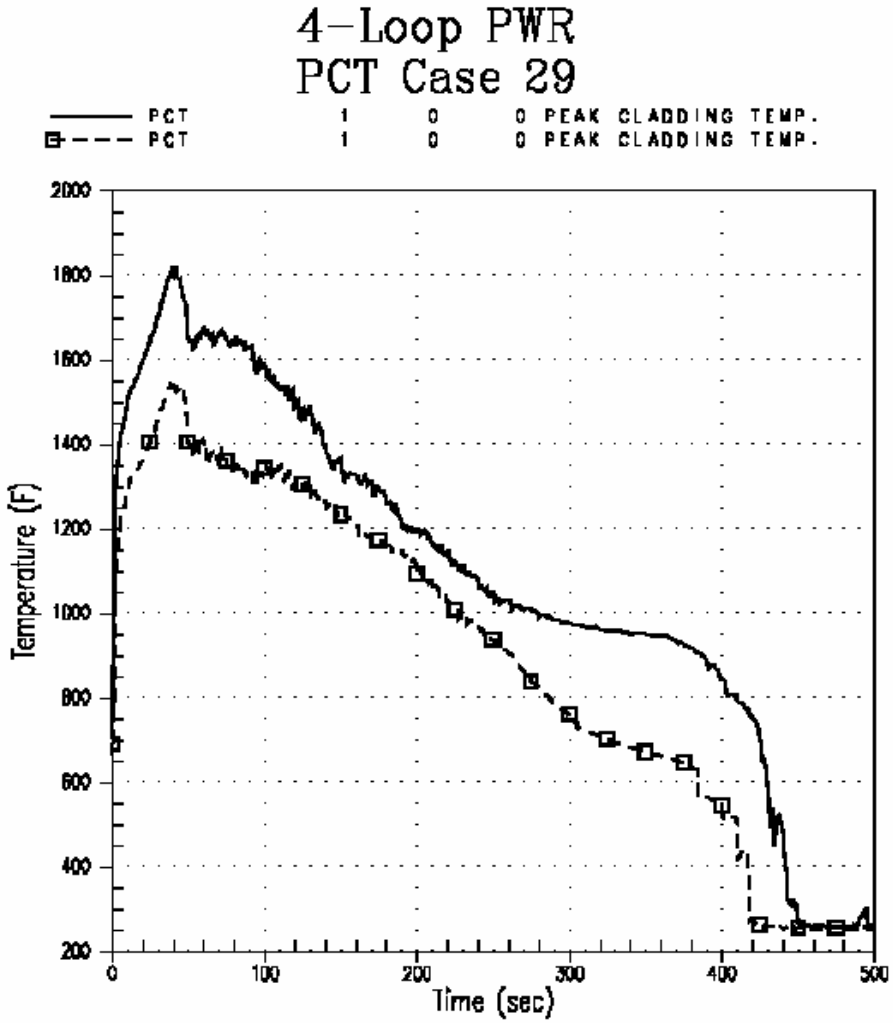
- Fresh Fuel: Worst Case = 1082°C (1980°F)
- High BU Fuel: All Cases < 860°C (1580°F)
- PCT Margin for High Burnup Fuel in Top 5 Fresh Fuel Cases Ranges from 152 – 249°C (274 – 449°F)

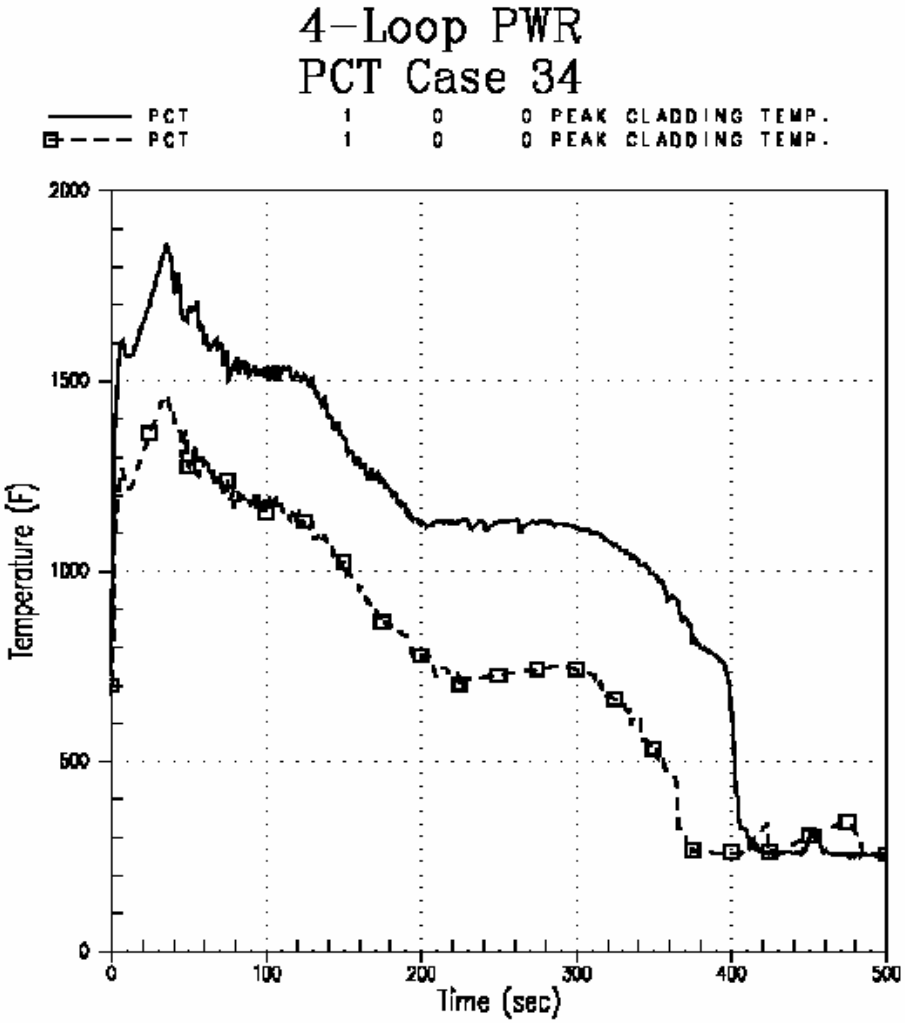
PCT Comparisons – Top Two Fresh Fuel Cases (WCOBRA / TRAC)



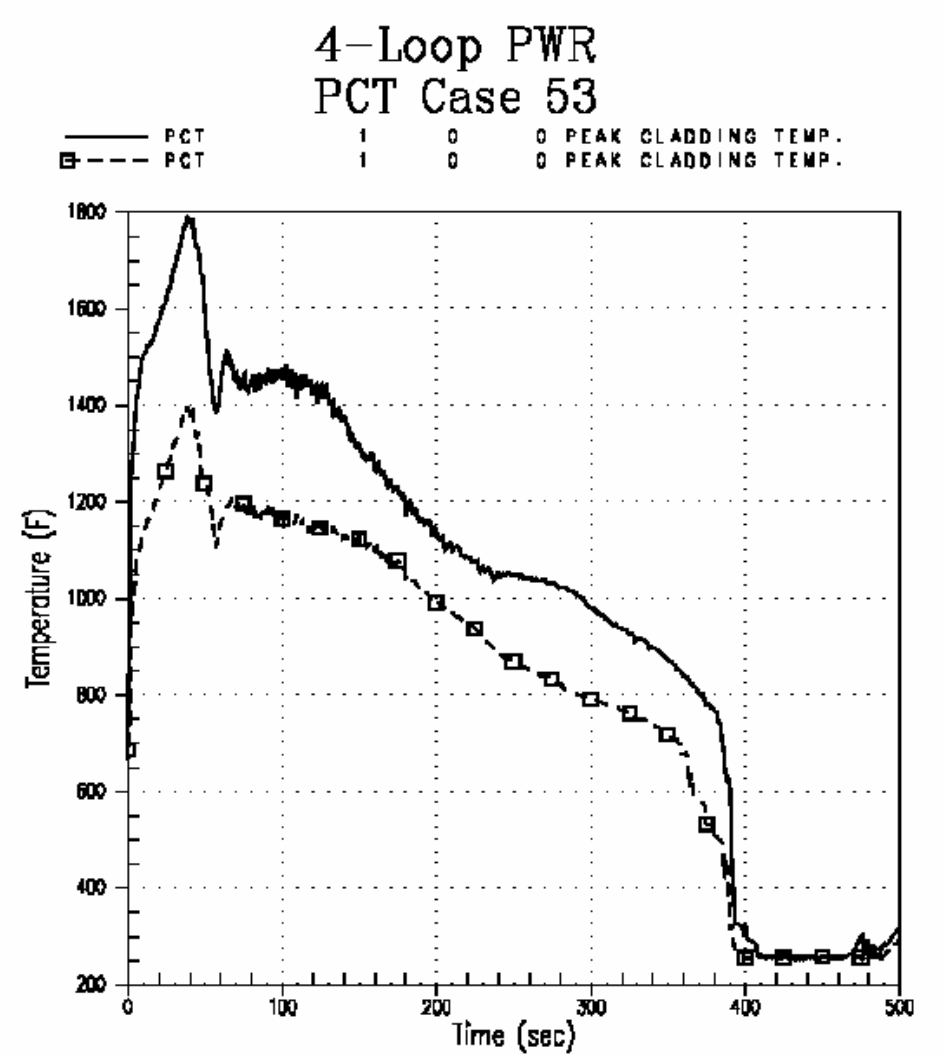


PCT Comparisons – 3rd and 4th Cases

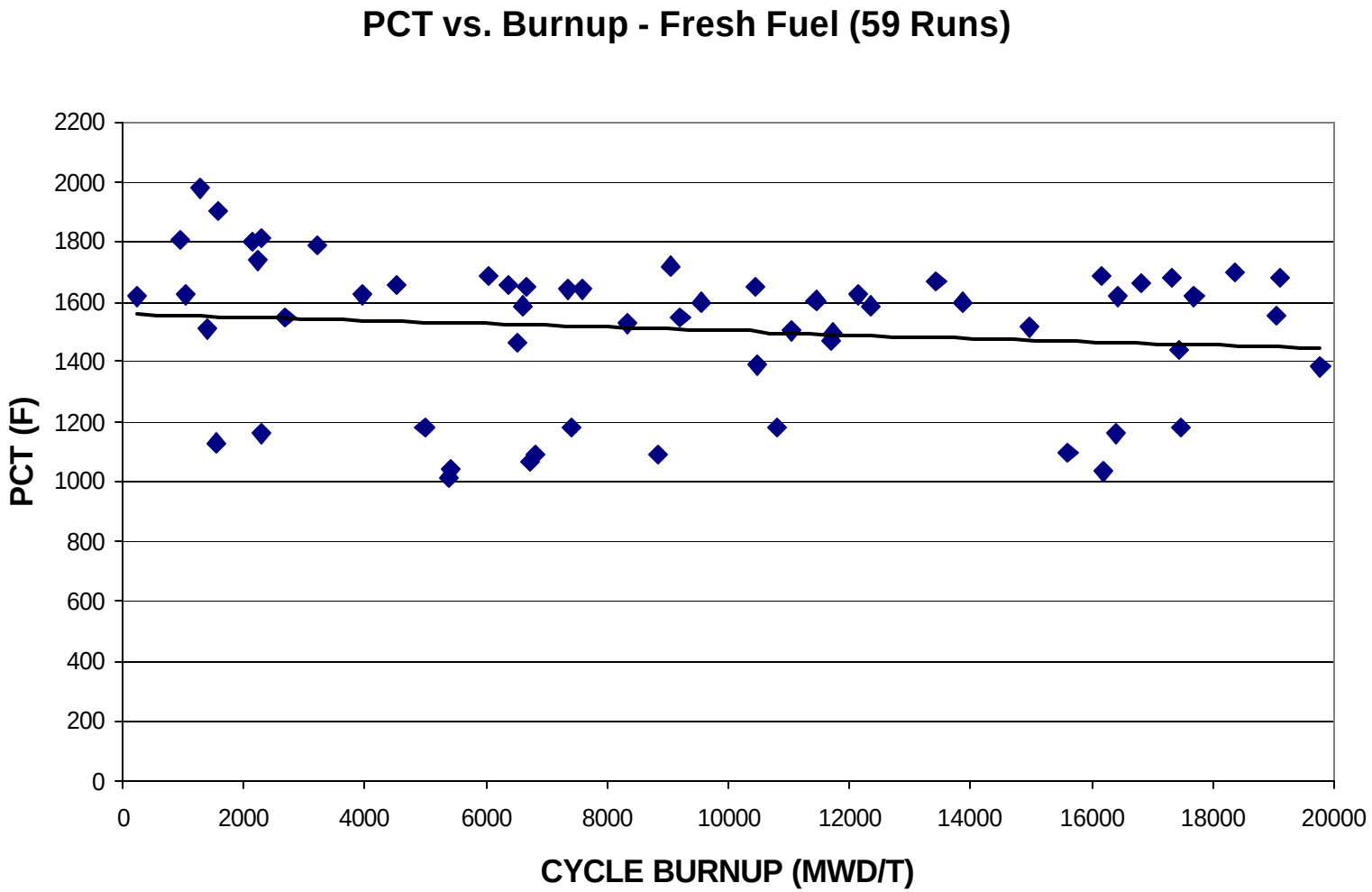




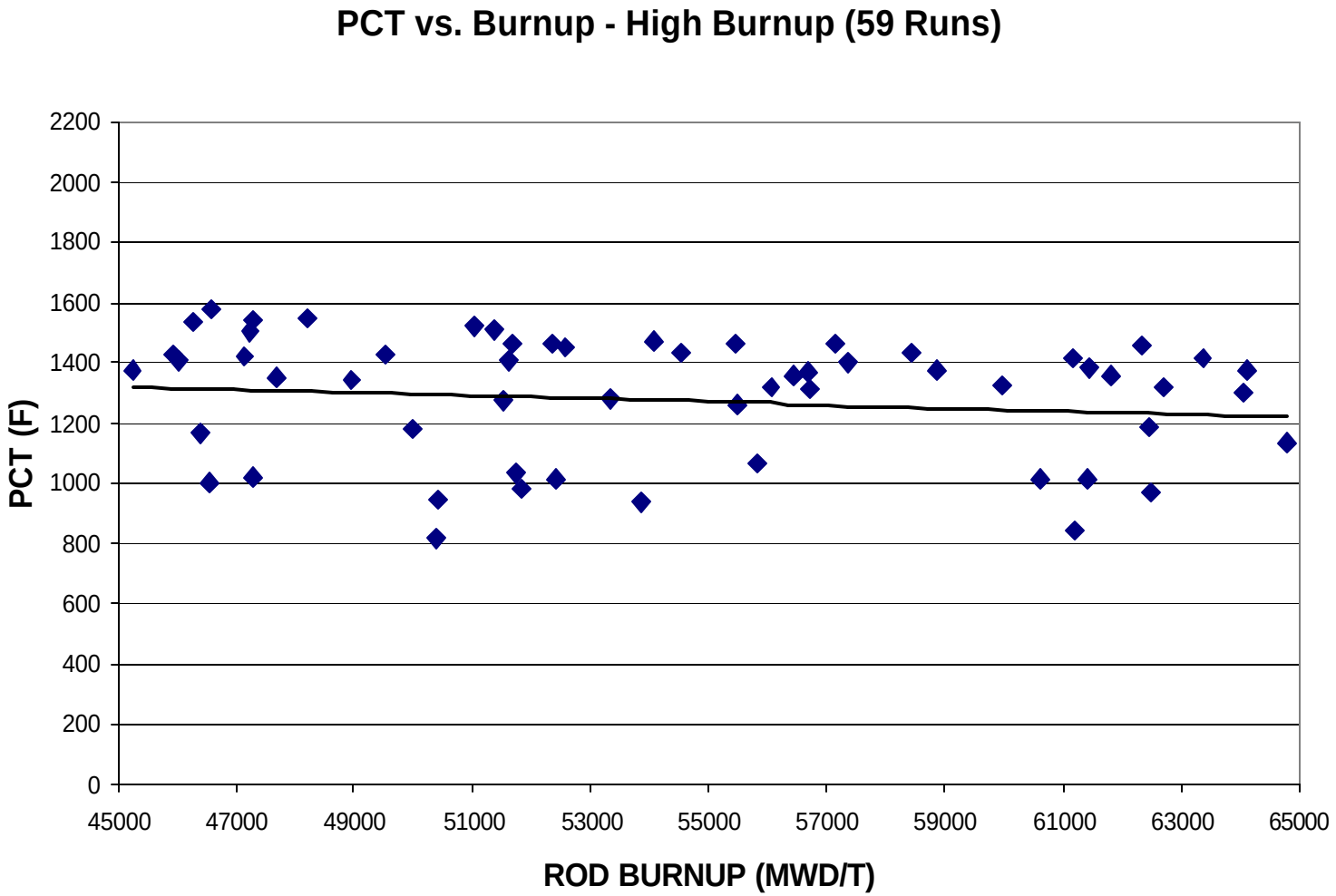
PCT Comparison – 5th Case



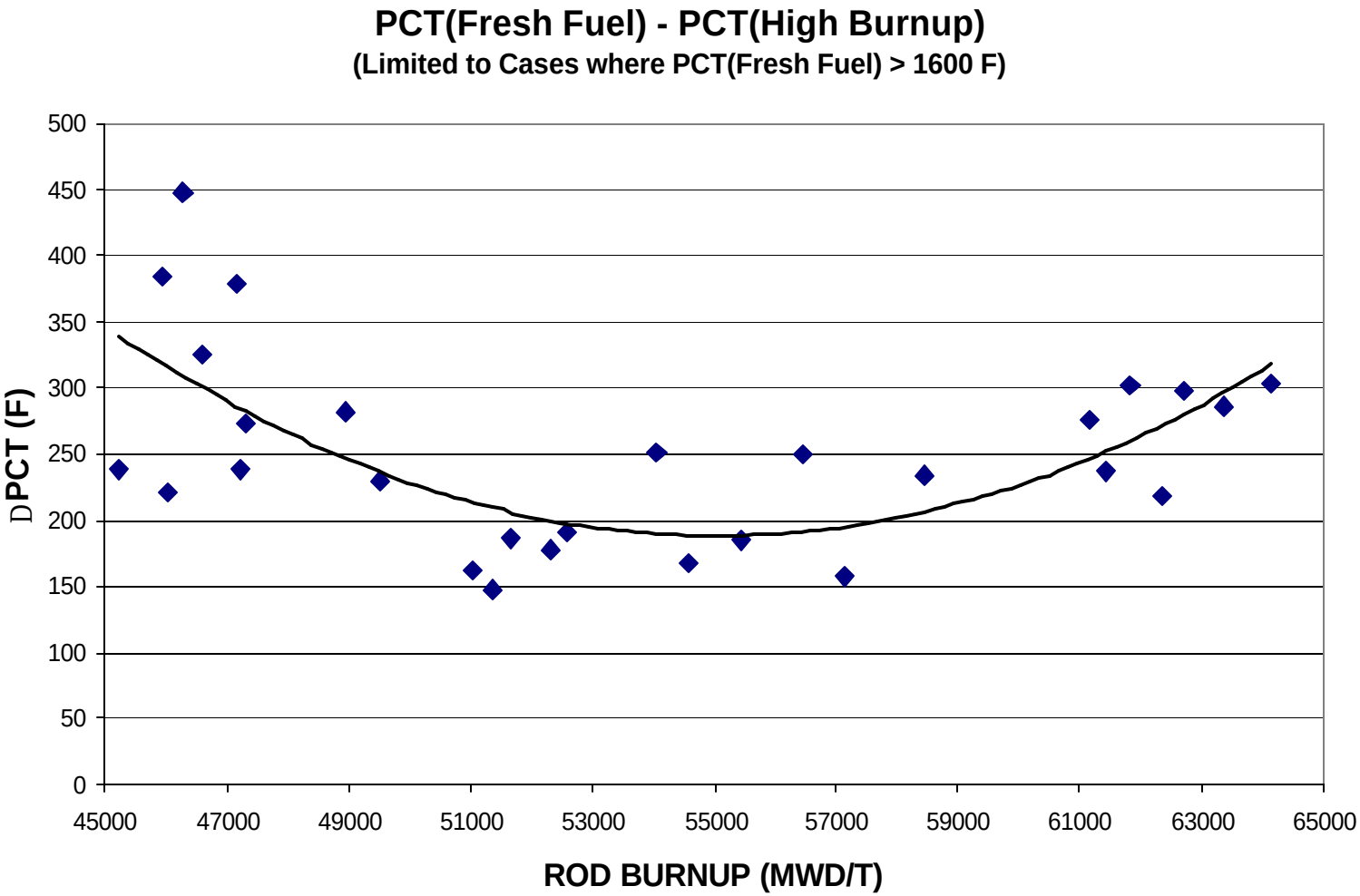
PCT Results for Fresh Fuel



PCT Results for High Burnup Fuel



PCT Comparisons vs Burnup



Factors Affecting ?PCT Through the Cycle

- Cladding Creepdown in Fresh Fuel Tends to Decrease ?PCT
- Thermal Conductivity Degradation in High Burnup Fuel (Not Modeled in Fresh Fuel) Tends to Decrease ?PCT
- Burndown Tends to Increase ?PCT

Conclusions / Implications

- Depletion of Fissionable Isotopes in UO_2 Fuel with Burnup Significantly Reduces the Achievable PCT for High Burnup Fuel
  - No High Burnup Case Exceeded 860°C (1580°F)

- Testing of High Burnup UO_2 Fuel to 1204°C (2200°F) Clearly Bounding, But Results Need to Be Considered in Realistic Context

  => Realistic oxidation in high BU UO_2 fuel expected to be negligible if fresh fuel satisfies 10 CFR 50.46