Determining MTR RIA Limits Using Experimental Data

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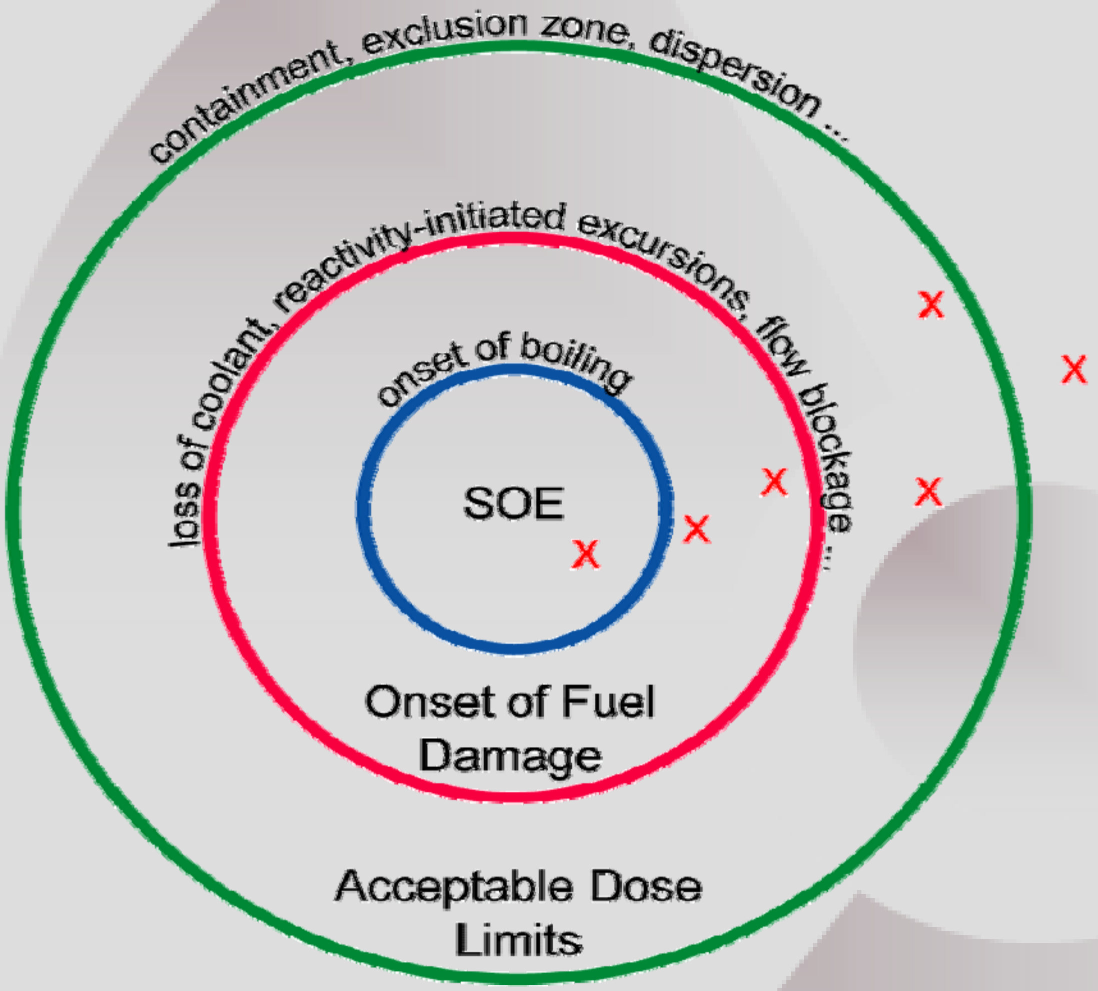
Outline

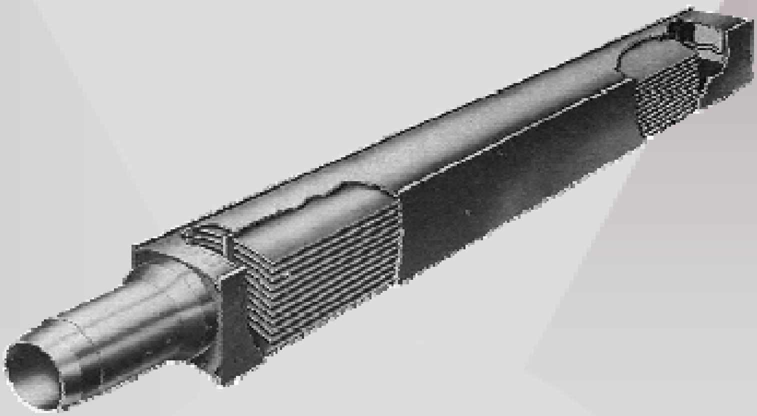
- Safety Analysis Context
- Reactor Experiments
- Transient Characteristics
- Methodology Outline
- Test Data Analysis
- Results
- Conclusions

Unprotected RIAs



Reactor Experiments

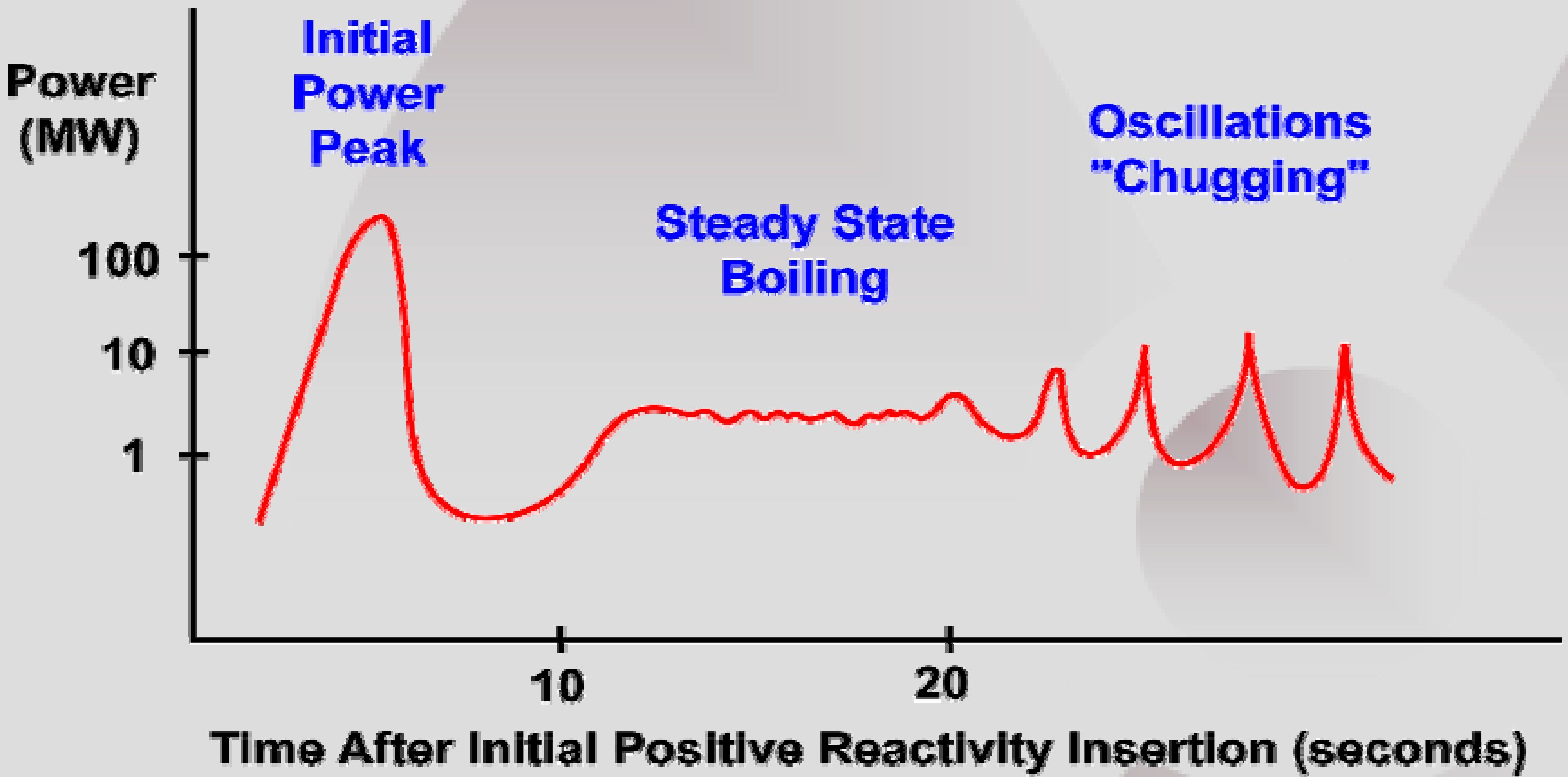
- BORAX & SPERT Tests
  - NRTS, USA 1950s/1960s
  - MTR-type HEU Reactors
  - Unprotected RIA Tests
  - Incremental Testing
  - Wide Range of System Parameters
  - Including Fuel Damage
  - Including Core Disassembly
  - PWR-type LEU Reactors
- SL-1 Reactor Accident (1962)



Experiment Set

System	Fuel Type	Enrichment	Cladding	Main Objective in Test Program
BORAX-I	Plate	HEU	Al	General Characteristics
SPERT I A	Plate	HEU	Al	General Characteristics
SPERT I B	Plate	HEU	Al	Void Reactivity
SPERT I P	Plate	HEU	SS	Cladding Material
SPERT I BSR-II	Plate	HEU	SS	Inherent *vs.* Mechanical Shutdown
SPERT I SA	Rod	LEU	SS	Power Reactor Fuel
SPERT I D	Plate	HEU	Al	Destructive Testing
SPERT I OC	Rod	LEU	SS	Destructive Testing
SPERT III C	Plate	HEU	SS	Power Reactor Conditions
SPERT III E	Rod	LEU	SS	Power Reactor Conditions
SPERT IV D	Plate	HEU	Al	Stability & Coolant Flow
SL-1	Plate	HEU	Al	Operating Reactor
IAEA Benchmark	Plate	HEU/LEU	Al	Simulation Problem

Transient Characteristics



Methodology Outline

- Quantifies Differences in the Test Data in terms of System Parameters
  - **Core Size**
  - **Power Distribution**
  - **Void Reactivity Feedback**
  - **Subcooling**
  - **Fuel Enrichment**

- Provides period and reactivity limits, and
- Predictions of maximum power, energy generation and maximum fuel temperature

Data Analysis

- Shutdown Model

$$\frac{P'(t)}{P(t)} = \alpha_o - w\left[E\left(t - t_d\right)\right]^n$$

$$P_{max} = \frac{\alpha_o^{(n+1)/n}}{w^{1/n}} e^{(\alpha_o t_d - 1/n)}$$

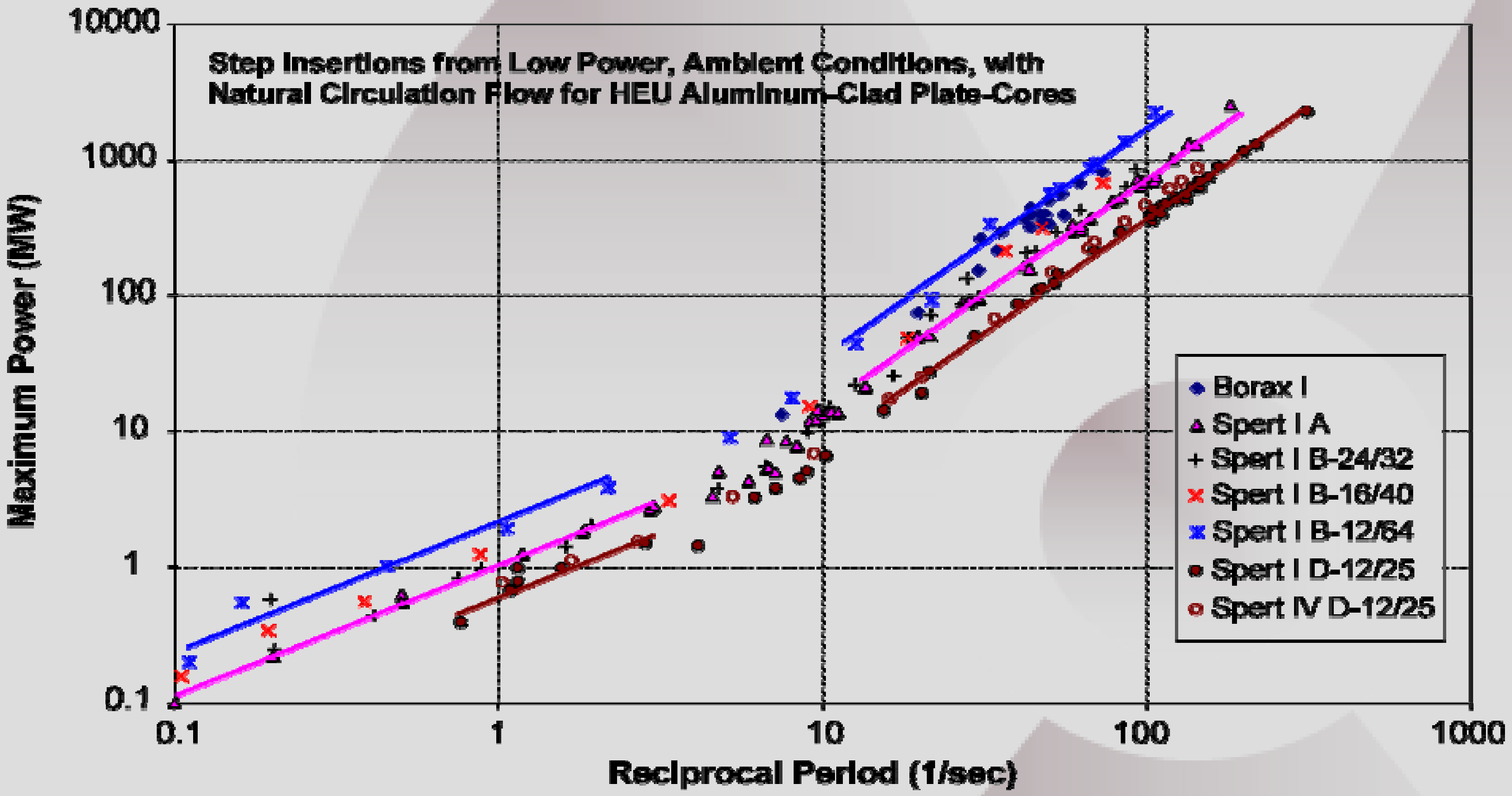
- Curve Fitting

$$P_{max} = b_1 \alpha_o^{m_1}$$

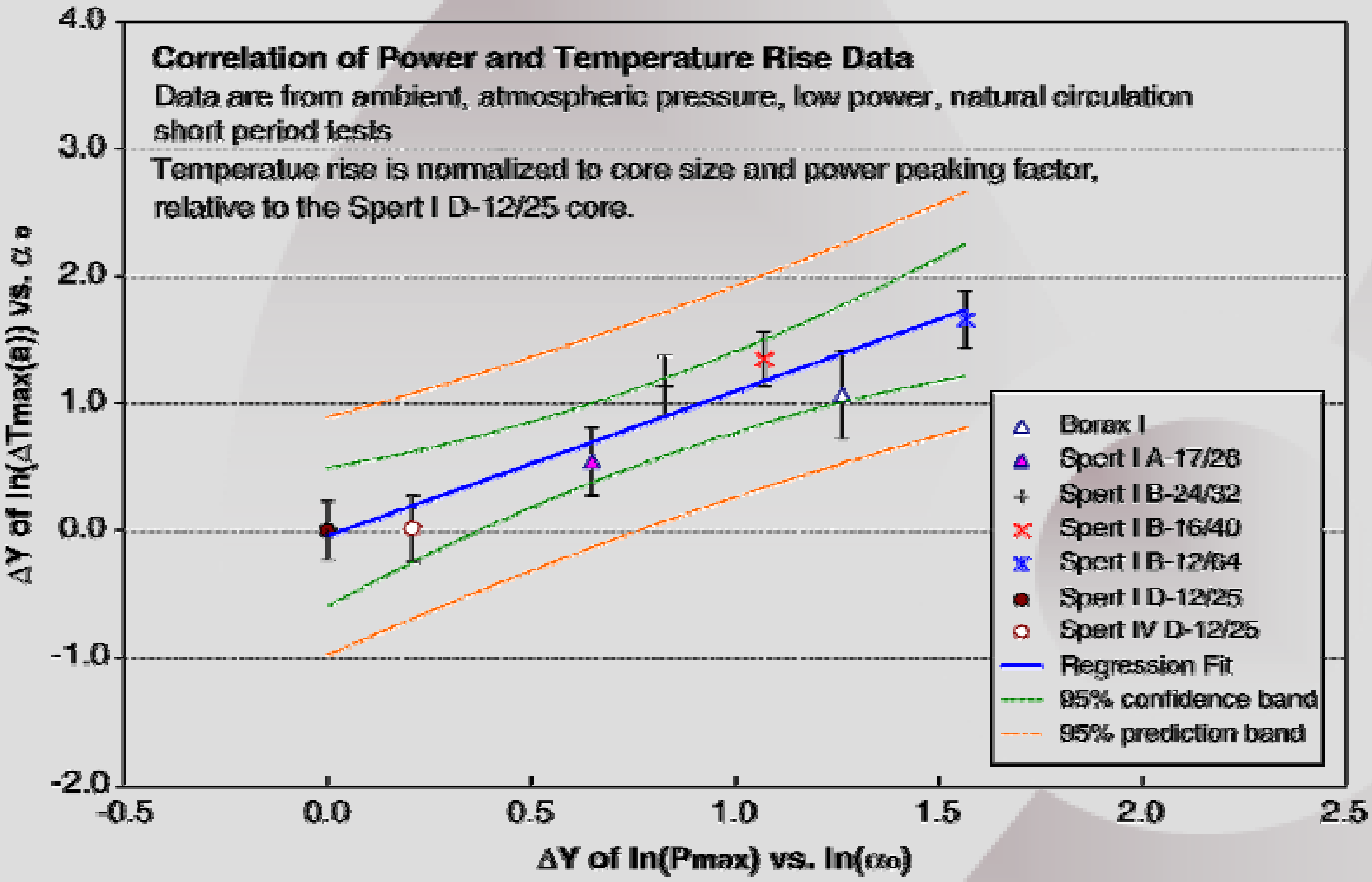
$$E_{tm} = b_2 \alpha_o^{m_2}$$

$$\Delta T_{max} = b_3 e^{\alpha_o m_3}$$

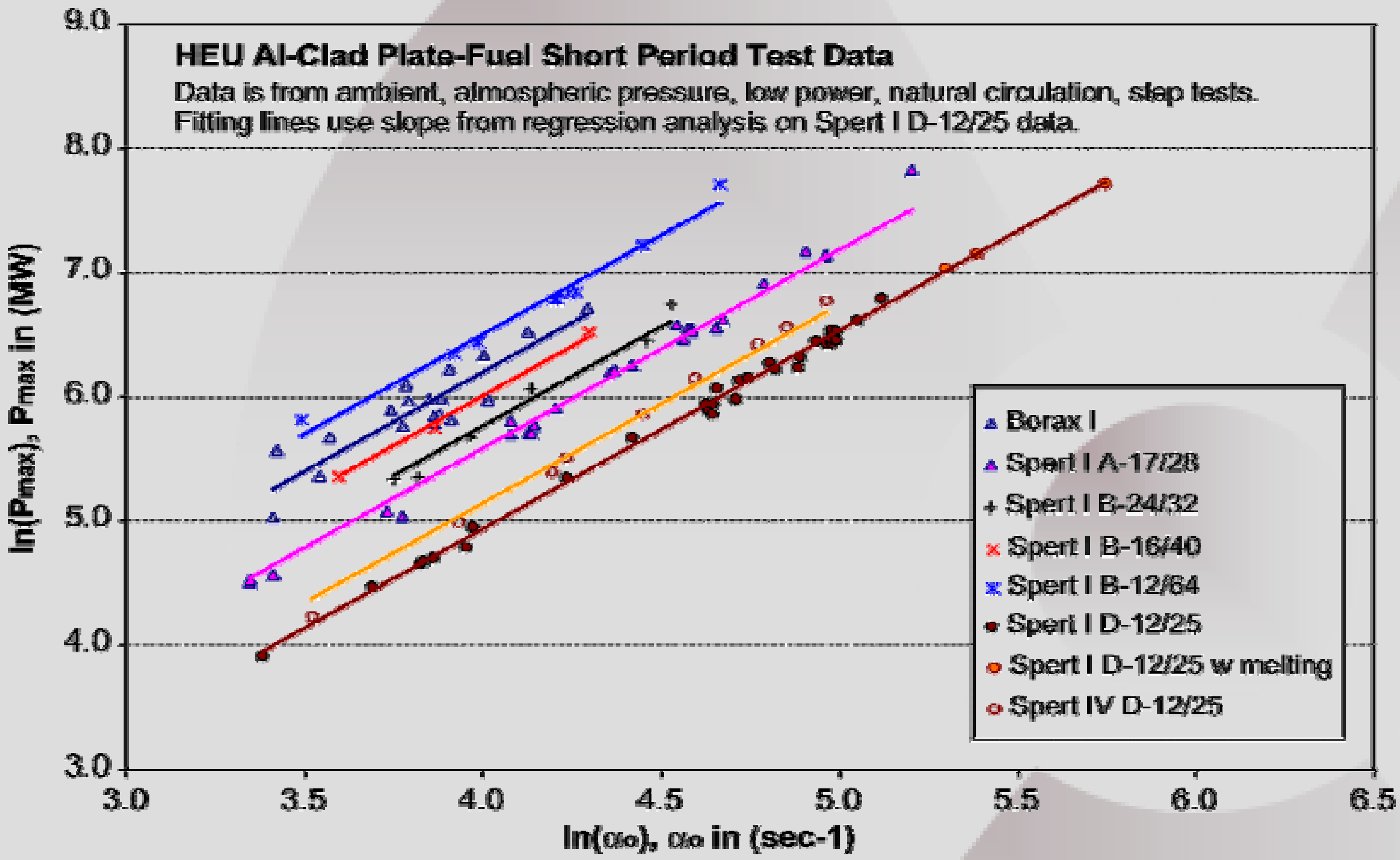
Reactor Test Data



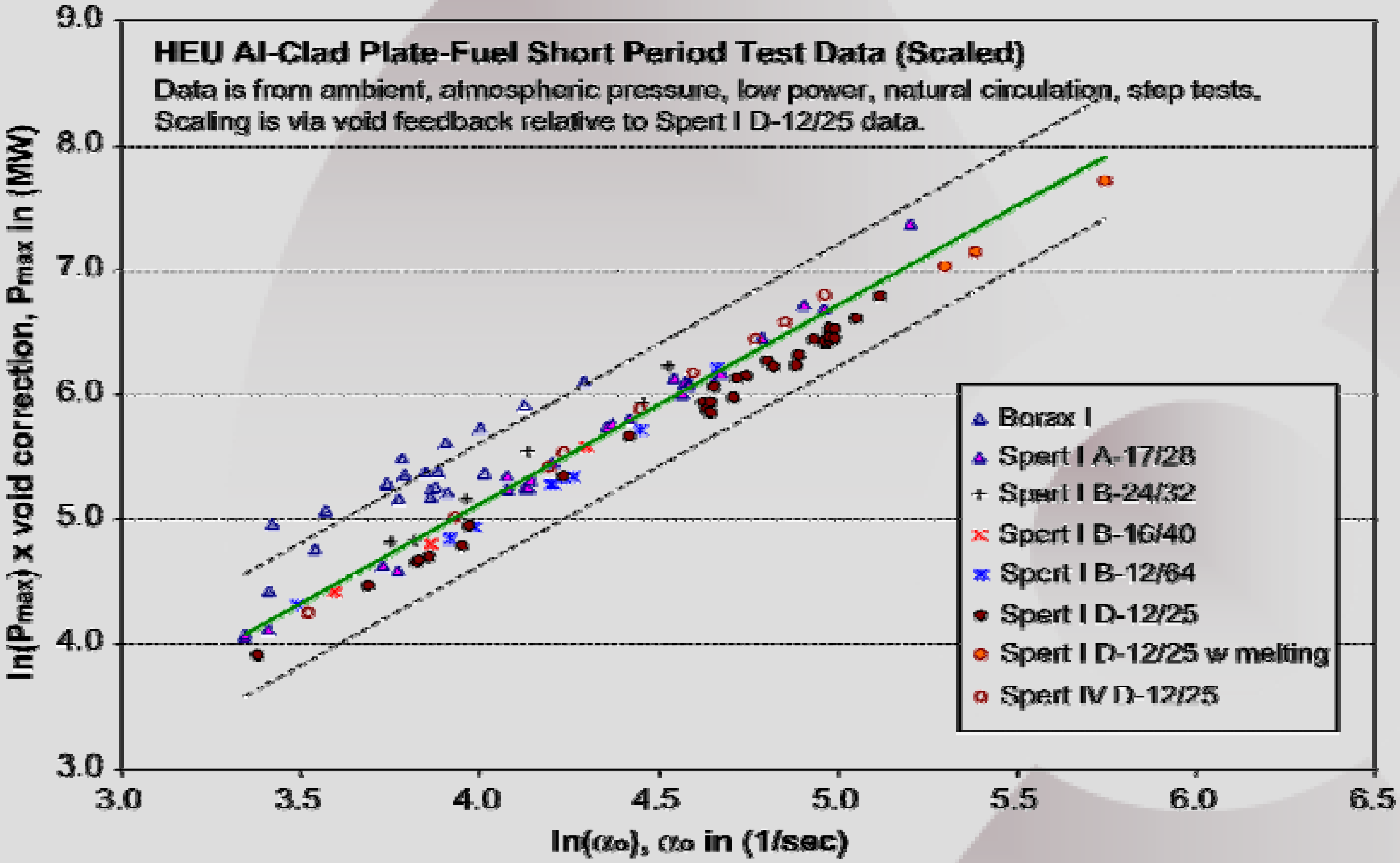
Maximum Power & Temperature



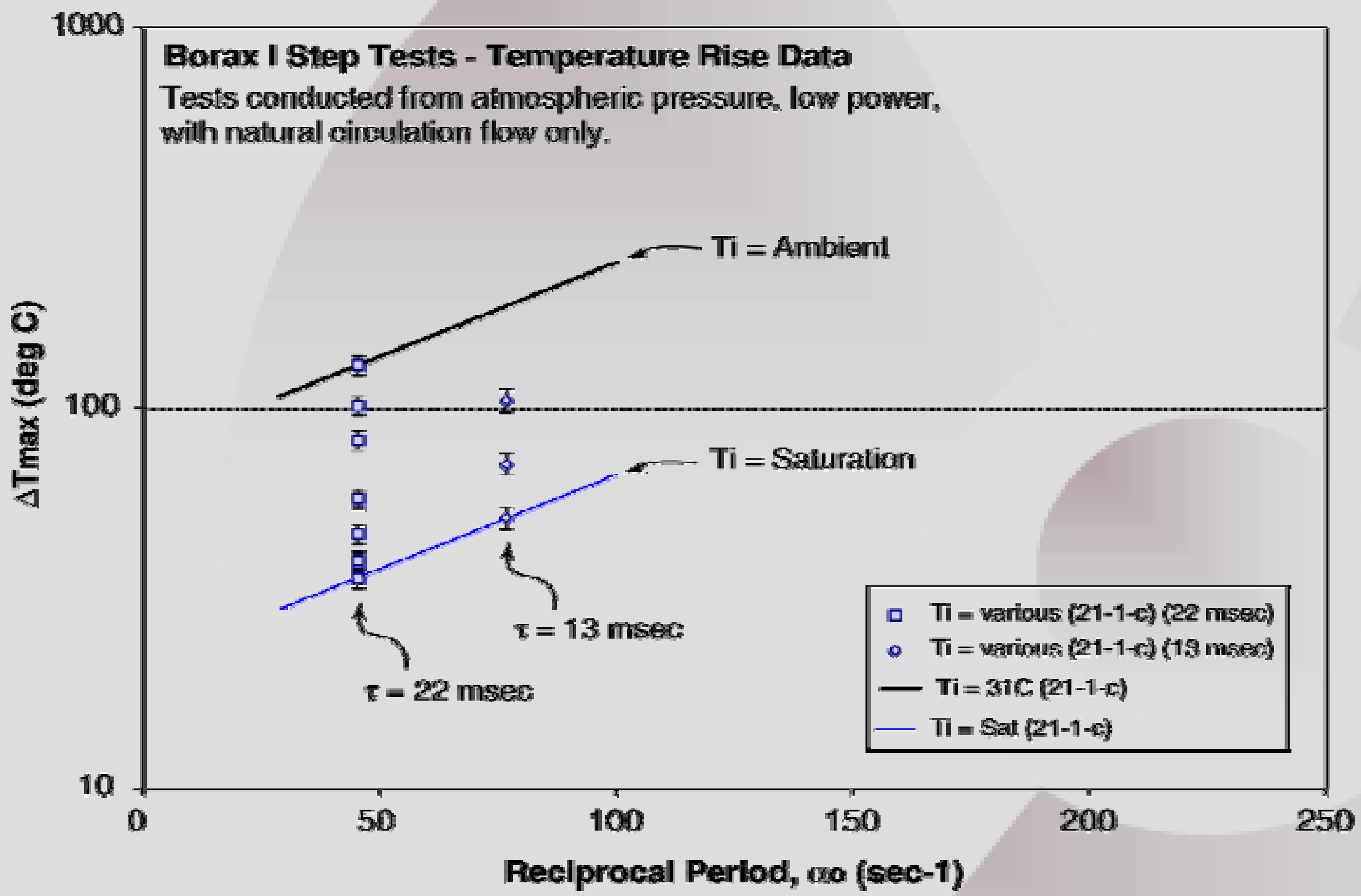
Variation with Void Reactivity



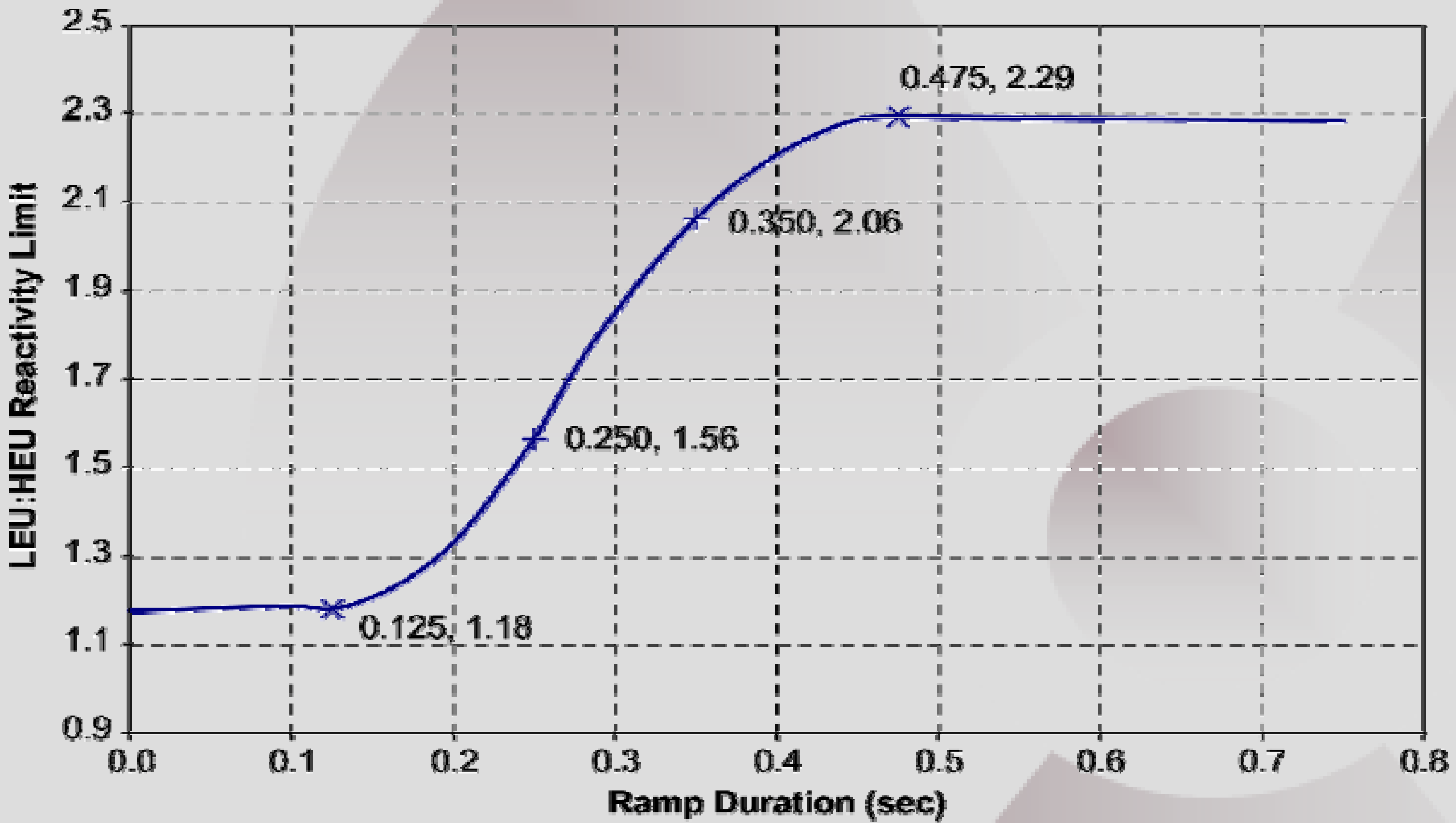
Variation with Void Reactivity



Variation with Subcooling



Extension to LEU Fuel



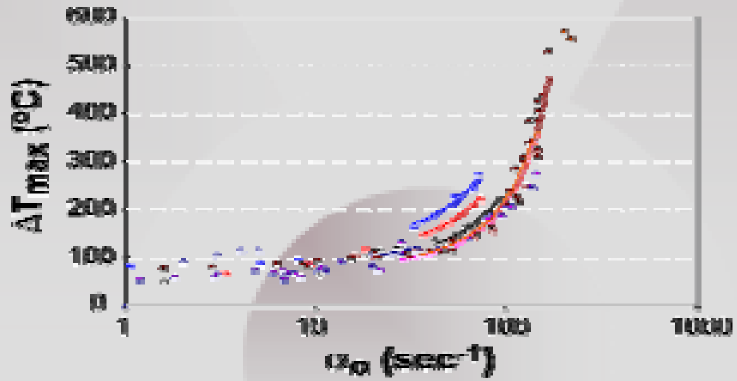
Methodology Results

- Methodology

$$\Delta T_{max}^{i} \times \frac{V_f^i}{V_f^{TC}} \times \frac{PPF^{TC}}{PPF^{i}} \times \left(\frac{w^i}{w^{TC}}\right)^{v} \times \frac{(1+s\times T_{sub}^{TC})}{(1+s\times T_{sub}^{i})} = \Delta T_{max}^{TC}$$

$$\Delta T_{max}^{TC} = b_3\, e^{\alpha_o m_3}$$

$$\rho_{limit}^{LEU} = \rho_{limit}^{HEU} \times \left(\frac{\rho_{limit}^{LEU}}{\rho_{limit}^{HEU}}\right)$$



- MNR LEU Reference Core
  - Conservative conditions & Irradiated fuel blistering temperature limit
  - Step insertion limit: 11 mk
  - Stability limit: 21 mk

Conclusions

- Reactor Test Data
  - Extensive data set
  - Transient characteristics
  - Identification of important system parameters

- Quantitative methodology for determining RIA limits
- Extension to PSA methods
- Alternative to simulation-based analysis
- Additional information for simulation validation

End

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