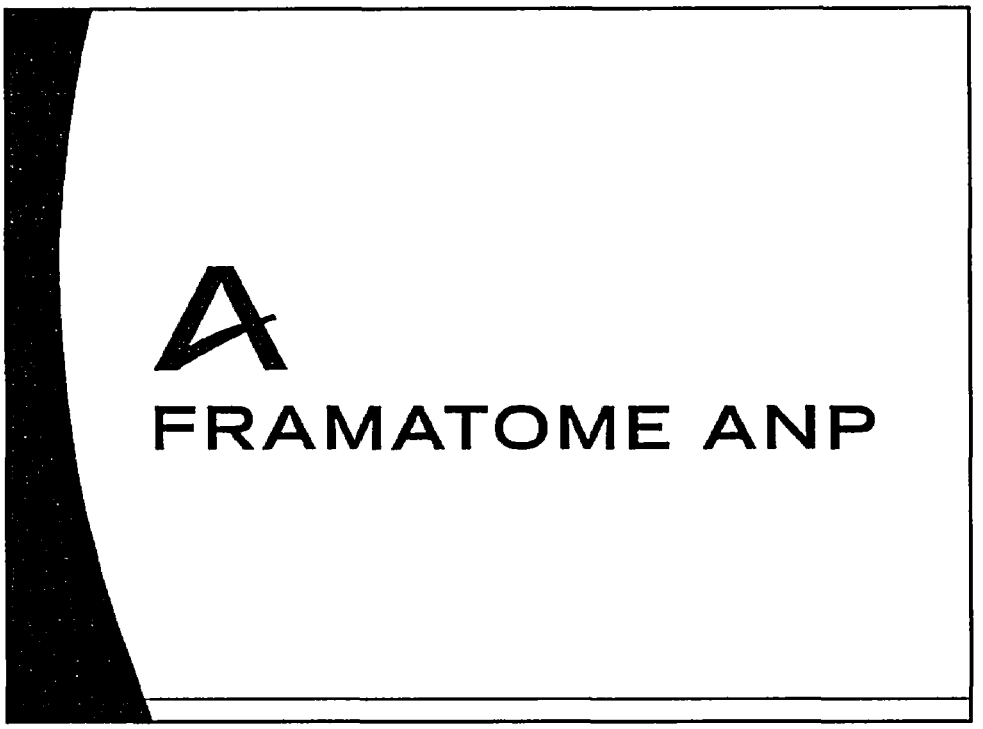

Dispersed Flow Film Boiling

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Research and Development Richland

Washington, D.C.
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Dispersed Flow Film Boiling

> Agenda

- S-RELAP5 Film Boiling Model
- Statistical Uncertainty
- Bias Evaluation

Dispersed Flow Film Boiling

> S-RELAP5 Model

- Single Phase Vapor Convection
  - Sleicher-Rouse
- Wall to Fluid Radiation (Vapor and Droplets)
  - Sun, Gonzalez, and Tien Model
- Dispersed Flow Film Boiling
  - Void fraction < 0.7, Modified Bromley
  - Void fraction >0.9, Forslund-Rohsenow
  - 0.7<Void Fraction<0.9, Interpolation

Dispersed Flow Film Boiling

> *Film Boiling Correlations*
- *Generally derived based on simplified experiments*
- *Use beyond derivation space requires additional validation*
- *Framatome has validated the application of these correlations in S-RELAP5 within the LBLOCA-space using data from a variety of testing programs, including THTF, FLECHT-SEASET, CCTF, LOFT, and SemiScale*
- *Framatome has evaluated the statistical uncertainty of the total heat transfer using data from THTF and FLECHT-SEASET*
  - *Insufficient data exists to develop uncertainties for the individual model components*

Dispersed Flow Film Boiling

> *Statistical Uncertainty*
- *THTF*
  - *Transient flooding tests (1.1 – 6.5 in/s)*
  - *High Pressure (400-1100 psia)*
  - *Full Height*
  - *Uniform rod power between 0.8 - 2.2 kw/ft*
  - *Rod Bundle in 8x8 array (60 heated rods)*
  - *Rod bundle design (P/D) consistent with 17x17 assemblies*
- *Tests 3.02.10C,D,E,F,G,H, and 3.09.10Q,R,S*

Dispersed Flow Film Boiling

- > Statistical Uncertainty
  - FLECHT-SEASET
    - Transient reflood (0.81-6.0 in/s, 5/8 tests at ~1 in/s)
    - Low Pressure (20,40,60 psia)
    - Full Height
    - Rod peak power ~.7 kw/ft, ANS + 20% decay power
    - Rod bundle 161-rod
    - Rod bundle design (P/D) consistent with 17x17 assemblies
  - Tests 31203, 31302, 31504, 31701, 31805, 32013, 34209

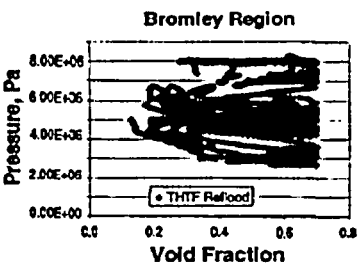
Dispersed Flow Film Boiling

- > Statistical Uncertainty
  - Relevance to scale and geometry
    - Assemblies are typical of 17x17 bundles
    - 15x15 bundles supported in evaluation of biases
  - Adequate breadth of LBLOCA-space
    - Table 5.1 EMF-2102
  - Adequate density of data
    - Visible inspection

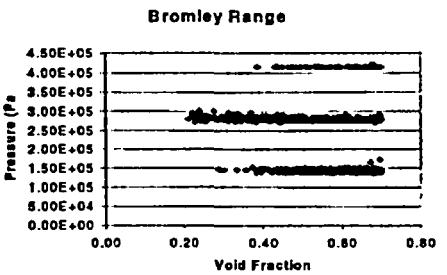
Dispersed Flow Film Boiling

> *Statistical Uncertainty*

THTF



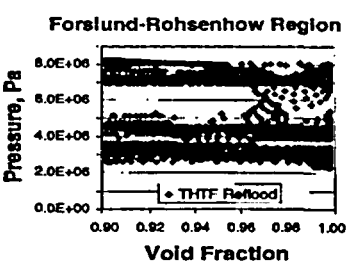
FLECHT-SEASET



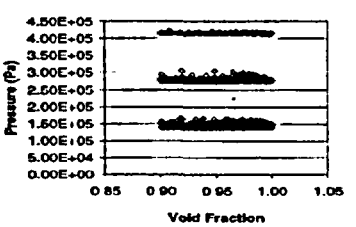
Dispersed Flow Film Boiling

> *Statistical Uncertainty*

THTF



FLECHT-SEASET

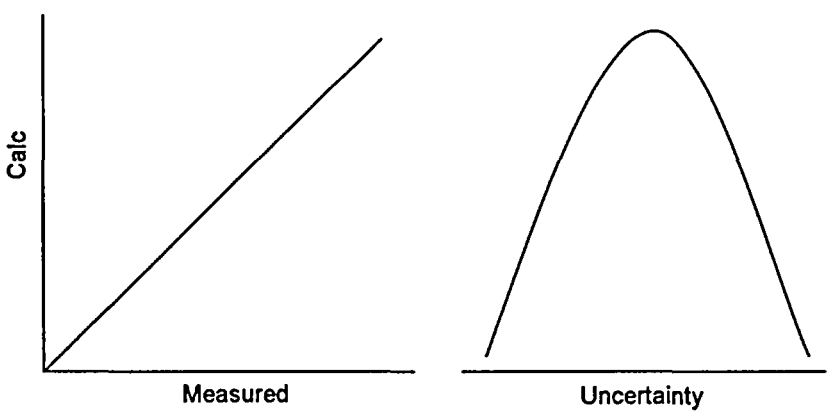


Dispersed Flow Film Boiling

> *Statistical Uncertainty*

- *Distributions given on page 4-97 of EMF-2103*

Dispersed Flow Film Boiling



Dispersed Flow Film Boiling

- > The Biases and Uncertainties address the disagreement between the model and data
  - The better the model the smaller the bias and the smaller the uncertainty distribution, conversely a poorer model will have a large bias and uncertainty
    - Both types of models are equally addressed in a non-parametric statistical analysis
    - This is clearly recognized in the CSAU methodology
  - Also covers the impact of not having a rod-to-rod radiation model
    - Not having an explicit rod-to-rod radiation model means that the scatter between the measured and calculated heat transfer coefficients will be larger for the tests where radiation is important, resulting in a larger overall uncertainty

Dispersed Flow Film Boiling

- > Validation of Code Biases
  - Code biases were developed based on various separate effect tests
  - Biases were then applied to other independent data sets
    - CCTF
    - LOFT
    - Semiscale
  - If the biases are appropriate, the comparison of code to data for these independent data sets should be improved

Dispersed Flow Film Boiling

> *Applied Biases*

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Dispersed Flow Film Boiling

> *Forslund-Rohsenow Impact*
  - *Two additional evaluations were performed with the Forslund-Rohsenow correlation turned off*
    - *FLECHT-SEASET impact on PCT*
    - *CCTF impact on PCT and quench time*

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> *Forslund-Rohsenow Impact*
  - *FLECHT-SEASET Tests*

	Temperature (°F)			
	Meas	K = 0.2	K=0.0	$T_{0.0} - T_{0.2}$
31805(0.81 in/s)	2218	2257	2239	-18
31504(0.97 in/s)	2022	2137	2138	+ 1
31203(1.51 in/s)	1842	1929	1905	-24
31302(3.0 in/s)	1651	1709	1712	+ 3
31701(6.1 in/s)	1659	1626	1646	+20
32013(1.04 in/s)	2071	2082	2073	- 9
34209(1.07 in/s)	2060	2194	2204	+10

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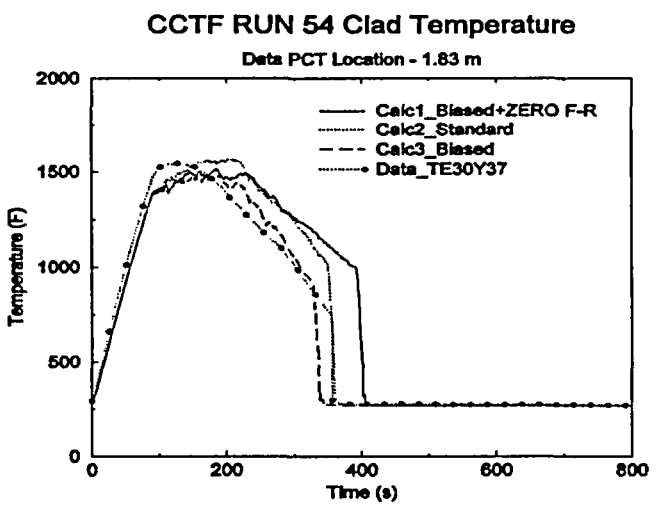
CCTF TEST 54 Temperatures at Measured PCT Node



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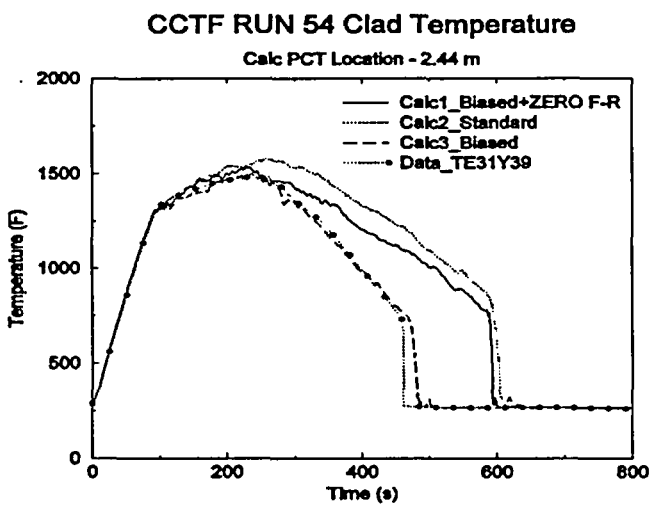
CCTF TEST 54 Temperatures Near Calculated PCT Node



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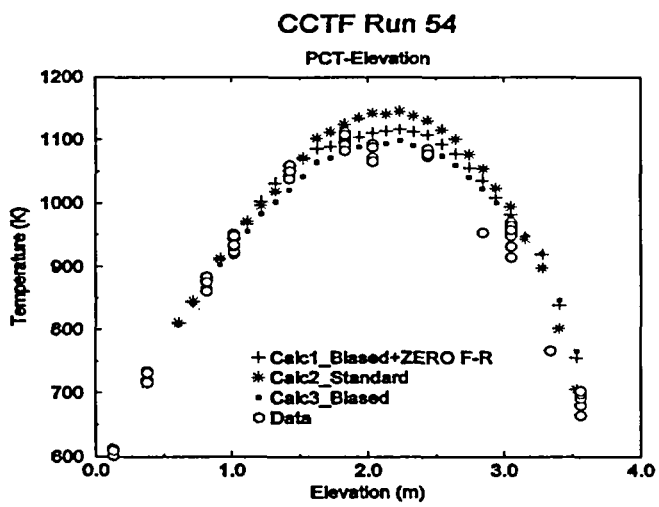
CCTF TEST 54 PCT Profile



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Heat Transfer Coefficients versus Void Fraction

Dispersed Flow Film Boiling

> Conclusions

- Current S-RELAP5 total film boiling model was defined
- Model evaluated against THTF and FLECHT-SEASET data
  - Bias and uncertainty distribution defined for total heat transfer coefficient
- Bias verified in comparison with independent data
  - CCTF, LOFT, and Semiscale
  - Application of biases improved agreement between calculated and measured PCT's and quench time
  - No indication of over prediction of heat transfer due to the lack of a rod-to-rod radiation model or the use of the Forslund-Rohsenow correlation
  - Turning off the Forslund-Rohsenow correlation adversely impacts the comparison to independent data