



Dispersed Flow Film Boiling
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Washington, D.C.
December 9, 2003

Dispersed Flow Film Boiling

> Agenda

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

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> 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*

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> 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*

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> 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*

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> 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*

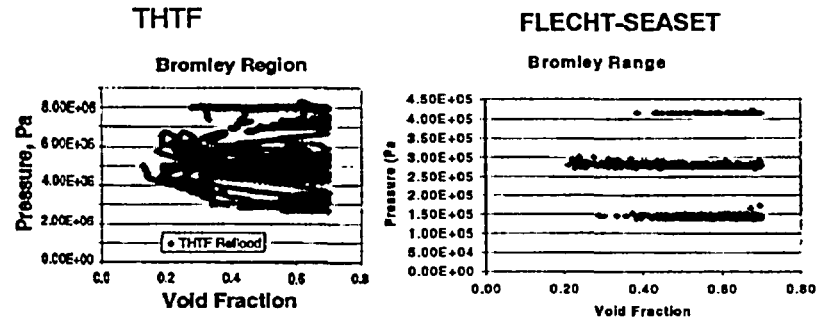
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> Statistical Uncertainty

- ♦ *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*

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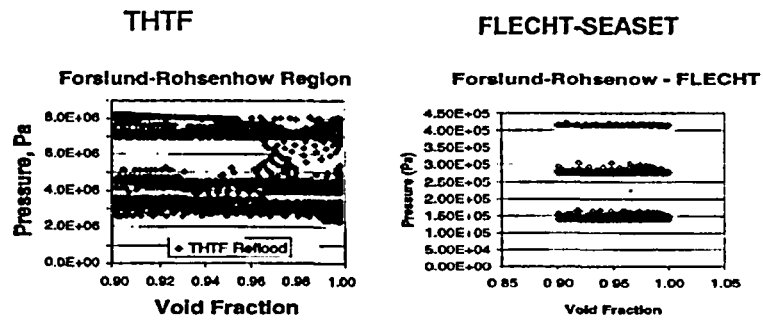
> Statistical Uncertainty



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> Statistical Uncertainty



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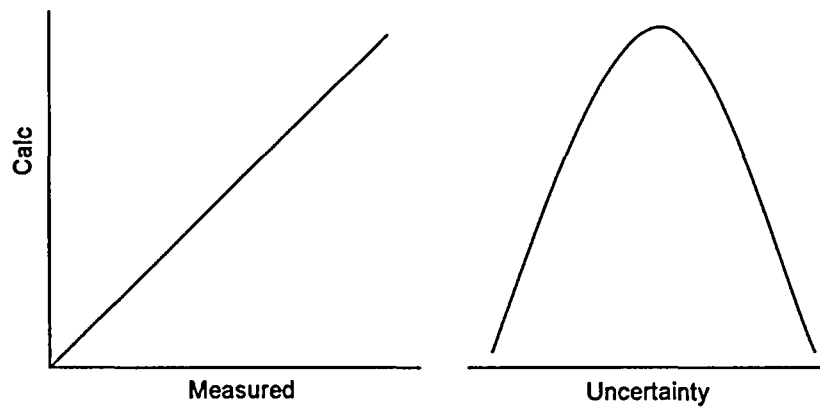
> **Statistical Uncertainty**

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

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> *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*

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> *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*

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> Applied Biases

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> 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

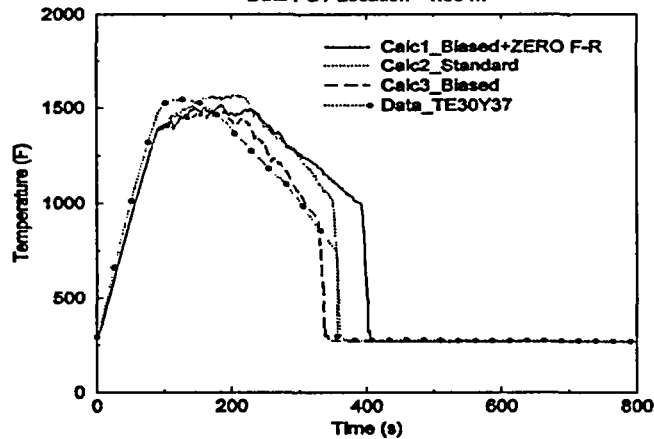
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CCTF TEST 54 Temperatures at Measured PCT Node

CCTF RUN 54 Clad Temperature

Data PCT Location - 1.83 m



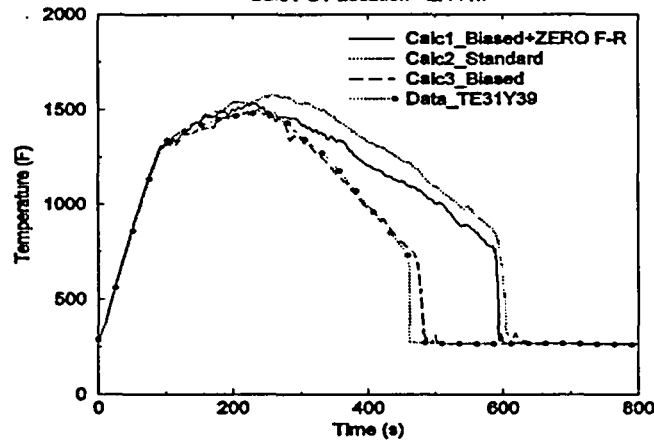
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CCTF TEST 54 Temperatures Near Calculated PCT Node

CCTF RUN 54 Clad Temperature

Calc PCT Location - 2.44 m



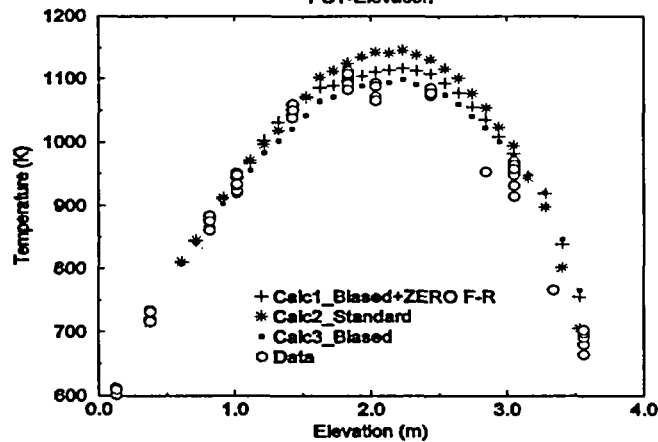
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CCTF TEST 54 PCT Profile

CCTF Run 54

PCT-Elevation



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Heat Transfer Coefficients versus Void Fraction



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> 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**

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