ASSESSMENT OF RELAP4/MOD6

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The RELAP4/MOD6[1,2] transient analysis code is the most recently released version of the set of computer programs designed for calculation of the thermal-hydraulic behavior of a light water reactor (LWR) during the transient phases of a postulated loss-of-coolant accident. Earlier versions of RELAP4 primarily had the capability for analysis of blowdown and refill phenomena. With the advent of RELAP4/MOD6, this capability has been extended through the core reflood range, providing a best-estimate analysis code for the entire accident period.

The code has been assessed[3] by comparing and evaluating calculations with results of a broad selection of reactor safety experiments. This assessment represents a new procedure that incorporates the results of code-data comparisons and evalutions made under controlled user-oriented conditions and introduces a conventional statistical approach to the analysis of code prediction uncertainties. The assessment procedure quantifies the uncertainties in the code for a broad spectrum of experimental data. Experimental complexity ranged from the study of system component phenomena to the simulation of complete reactor primary coolant systems. The scope of calculations performed included base-case analyses in wherein code calculations are compared with the results of completed experiments and test predictions in which calculations were made prior to obtaining experimental results.

Capabilities and deficiencies inherent in recommended code input guidelines and in code internal model structure were defined as a direct result of the assessment study. Some of the more significant code capabilities demonstrated were (1) the adequate analytical representation of the hydraulics throughout the modeled systems for both blowdown and reflood, and (2) the matching of calculated and measured peak cladding temperature in blowdown separate-effects and systems-effects experiments and in reflood systems experiments. The success of the reflood analytical modeling in the code, new with the deveopment of RELAP4/MOD6, is reflected in the successful application of modified user guidelines developed in this study. Among the deficiencies identified were inadequacies of the code to calculate the refill period because of the homogeneous equilibrium assumptions in the code. In addition, specific empirical models, such as those governing entrainment and phase separation for reflood calculations and those composing the critical flow user guidelines, were inadequate.

REFERENCES

1. RELAP4/MOD5, A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactors and Related Systems, User's Manual, Volume 1, RELAP4/MOD5 Description, ANCR-NUREG-1335, (September 1976).

2. RELAP4/MOD6, A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactors and Related Systems, User's Manual, CDAP-TR-003, (January 1978).

3. Assessment of the RELAP4/MOD6 Thermal-Hydraulic Transient Code for PWR Experimental Applications, Volumes 1 and 2, CAAP-TR-78-035, (December 1978).

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TABLE I

REPRESENTATIVE CODE-DATA DIFFERENCES FOR BASE-CASE AND TEST PREDICTION ANALYSES

Separate Effects Analyses

Phase	Component	Parameter	Uncertainty or Error
Blowdown	Pressurizer	Pressure	5%
	Fuel Rods	Time to CHF	0.2 s
		Temperature Rise	50 K
	Core	Cladding Temperature	
		Short Core	Mean Error = 124 K Std Dev = 77 K
Reflood	Core	Cladding Temperature, Lower and Middle Core	100
		Liquid Inventory at Midplane Quench	4%

Systems-Effects Analyses

Phase	Parameter	Uncertainty or Error
Blowdown	System Pressure Prior to Accumulator Flow	2%
	Cladding Temperature	
	Short Core	70%
	Full-Length Core	Mean Error = -39 K Std Dev = 34 K
Reflood	Cladding Temperature Lower and Middle Core	100 K

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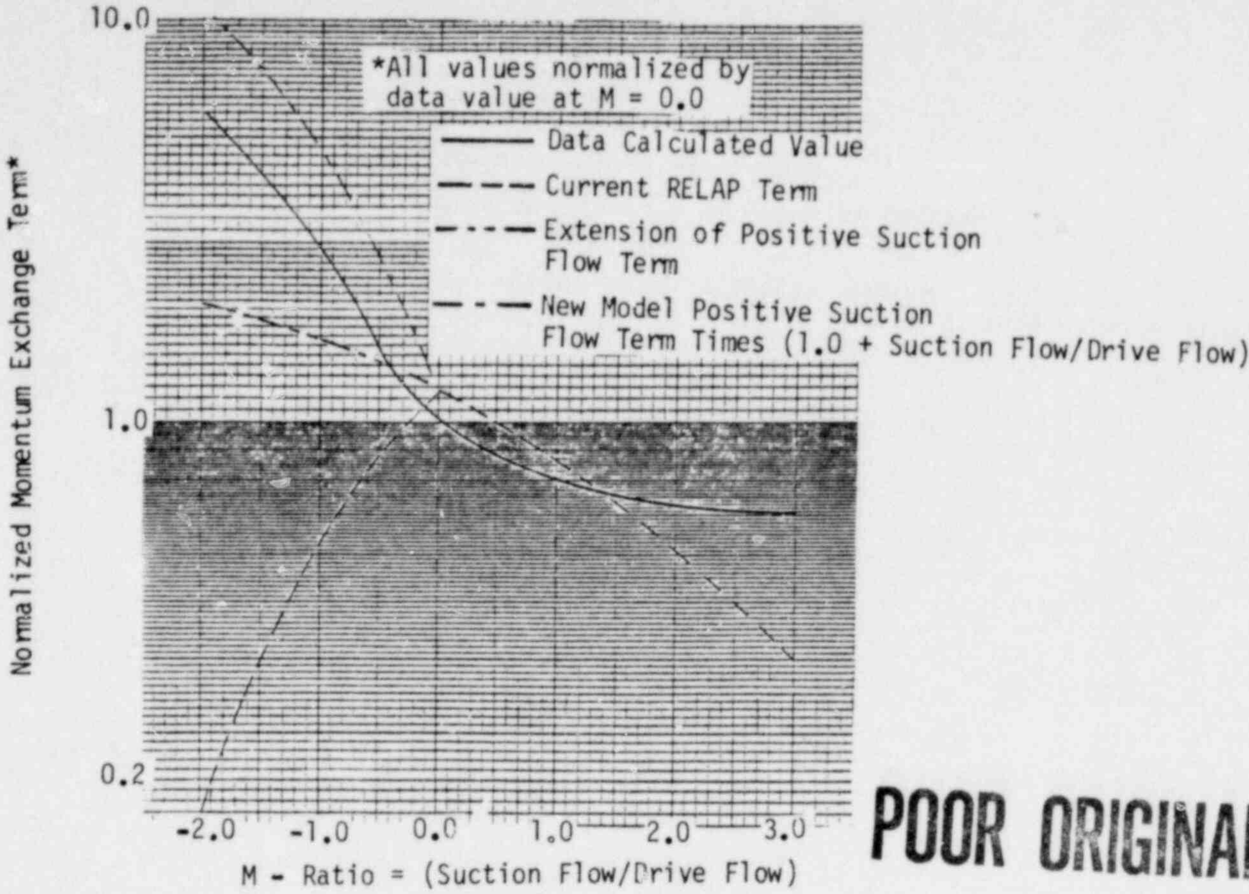

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Fig. 1 Normalized momentum exchange term vs. M-Ratio.

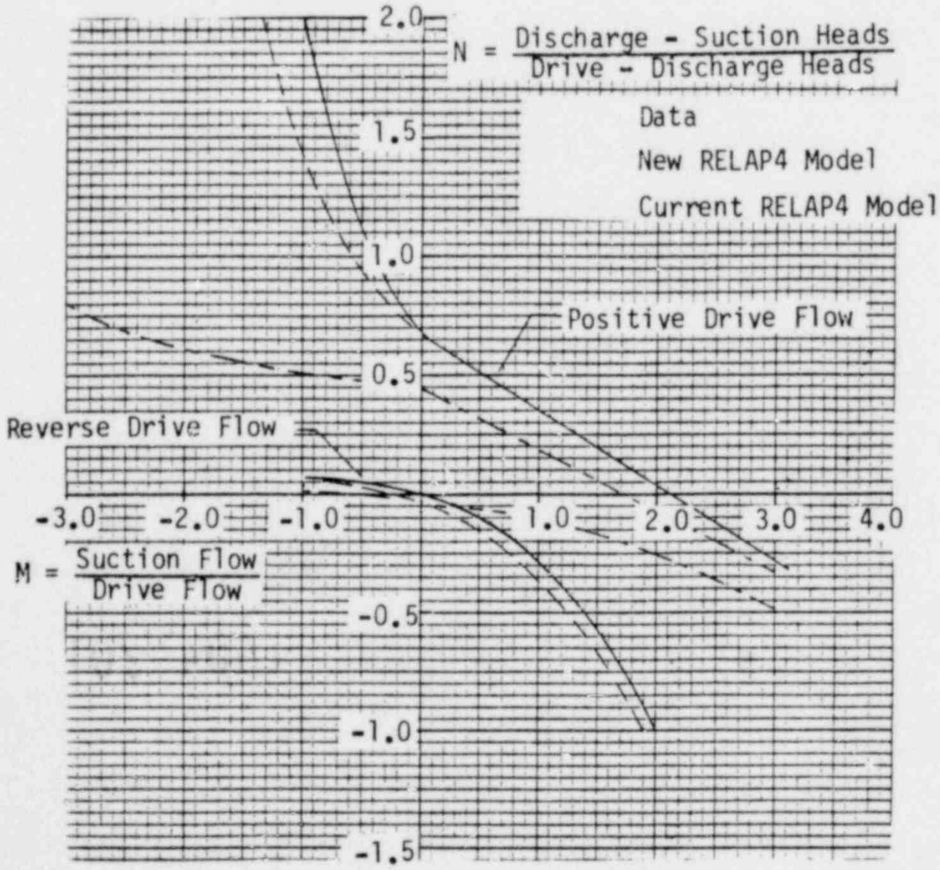

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Fig. 2 Model evaluation - Jet Pump characteristic curve.

Results
Blowdown Separate-Effects Subtasks

Component	Performance Evaluator	Uncertainty or Error
Pressurizer	Pressure	<5%
	Flowrate	<23%
Core	Cladding temperature	
	Short core	Mean error = 124 K
		Std dev. = 103 K
	Full-length core	Mean error = 110 K
		Std dev. = 77 K
Critical flow	Flowrate	Mean error = 17% ± 13%

RELAP4/MOD6 Assessment

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RELAP4/MOD6

- Developed at the INEL for NRC/RES by EG&G Idaho, Inc.

- Update 4 released to public in January 1978

- First version of RELAP4 code to have capability for reflood analysis

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Assessment Study Objectives

- Determine code and guideline capabilities and deficiencies in calculating behavior of loss-of-coolant experiments

- Implement assessment procedures and evaluate adequacy of:

    - Procedures

    - Experimental data base

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Experimental Data Base

Includes:

- NRC-sponsored experiments
- Foreign sources of experimental data
- Both separate-effects and systems-effects experiments

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Calculation Scope

- Base-case analyses
    - Code calculations compared with results of completed experiments
    - Test predictions made prior to obtaining experimental results

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Calculation Scope (cont'd)

- Sensitivity studies
  - Performed to provide understanding of differences between calculations and measurements
  - Make special evaluations of influential models and guidelines

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By-Products of Assessment

- Recommendations for code use
- Analysis of model applicability
- Samples of code applications

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Assessment Procedure

- Code evaluated against experimental data
- Performance evaluators and diagnostic indicators defined for each experiment
- Preparation of results in a form suitable for use in statistical analyses

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The Assessment Matrix

- Included experiments from Nine Facilities

- Subtasks were established to provide analyses in small segments of an overall broad scope of effort

- The experimental source and code capability being evaluated was indicated for each subtask

- Eighteen subtasks were defined for which forty one base case calculations were made

INEL-S-21 788

Results (cont'd) Blowdown Systems-Effects Subtasks

Component	Performance Evaluator	Uncertainty or Error
Vessel	System pressure prior to accumulator flow	<2%
Core	Cladding temperature	
	Short core	<70 K
	Full-length core	Mean error = – 39 K
		Std. dev. = 34 K

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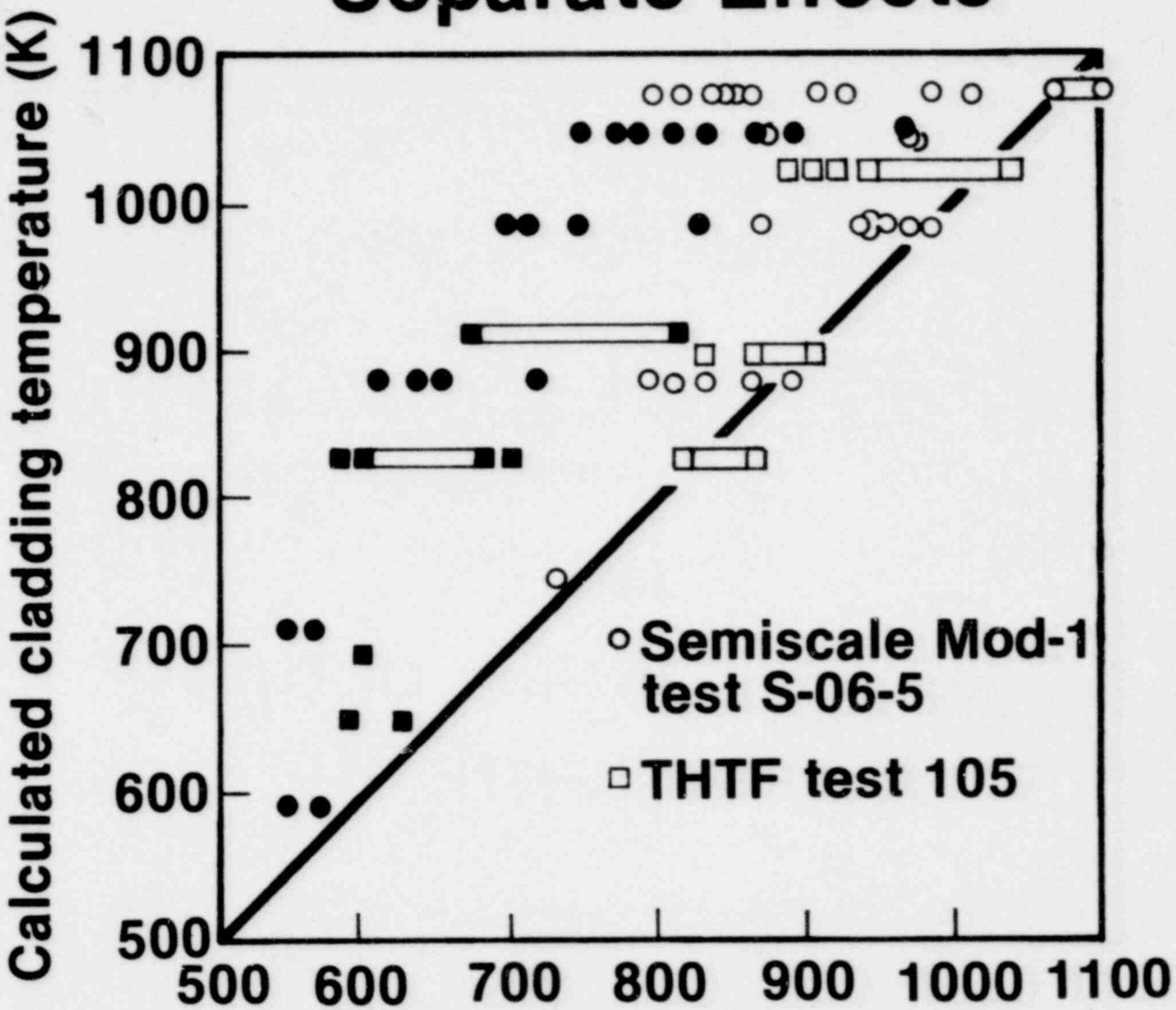
Maximum Cladding Temperature for Blowdown Separate Effects



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Results (cont'd) Reflood Separate-Effects Subtask

Component	Performance Evaluator	Error
Core	Cladding temperature,	
	Lower and middle core	<100 K
	Skewed power profile	<500 K
	Quench time	< ± 100%

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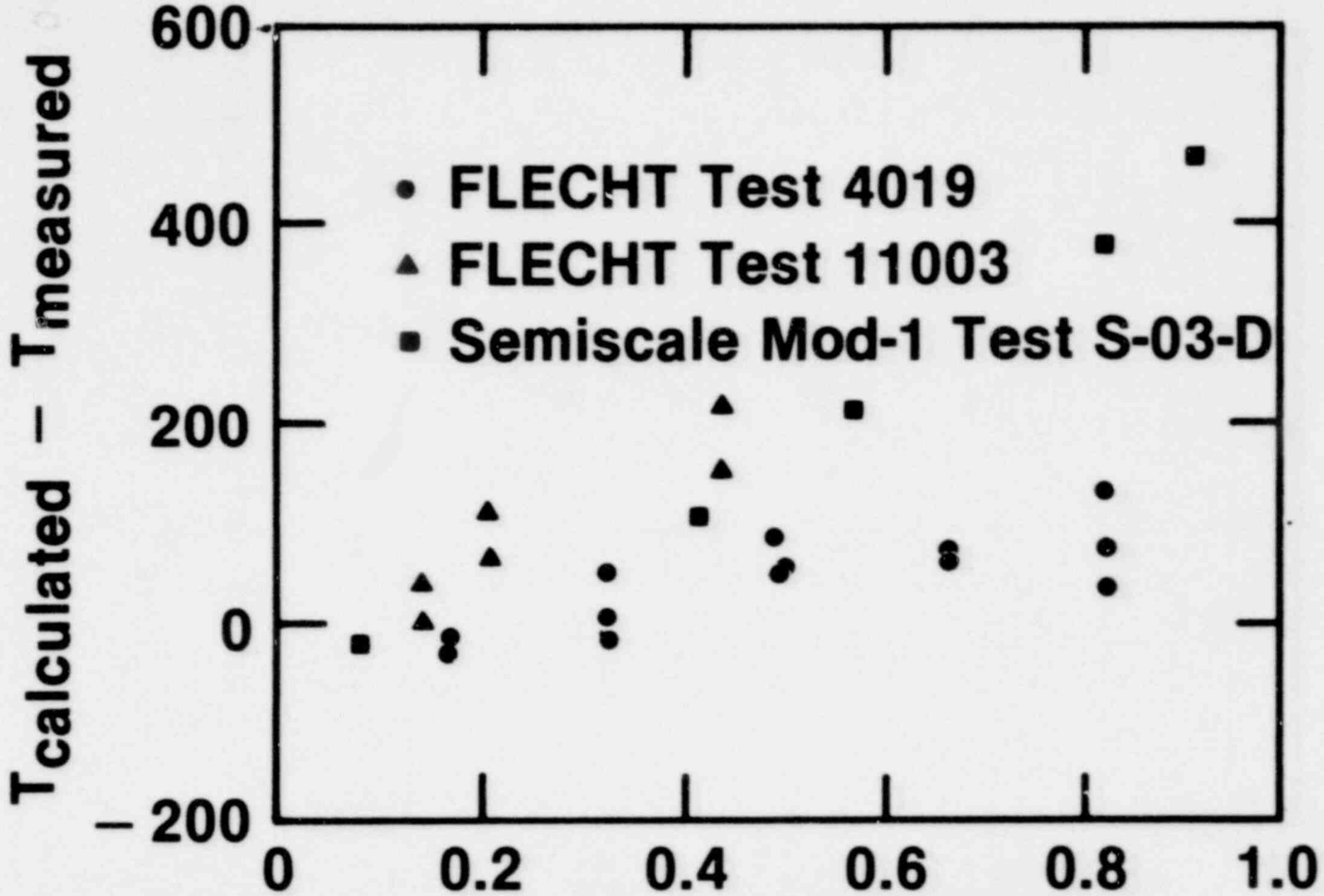
Error in Maximum Calculated Temperature During Reflood



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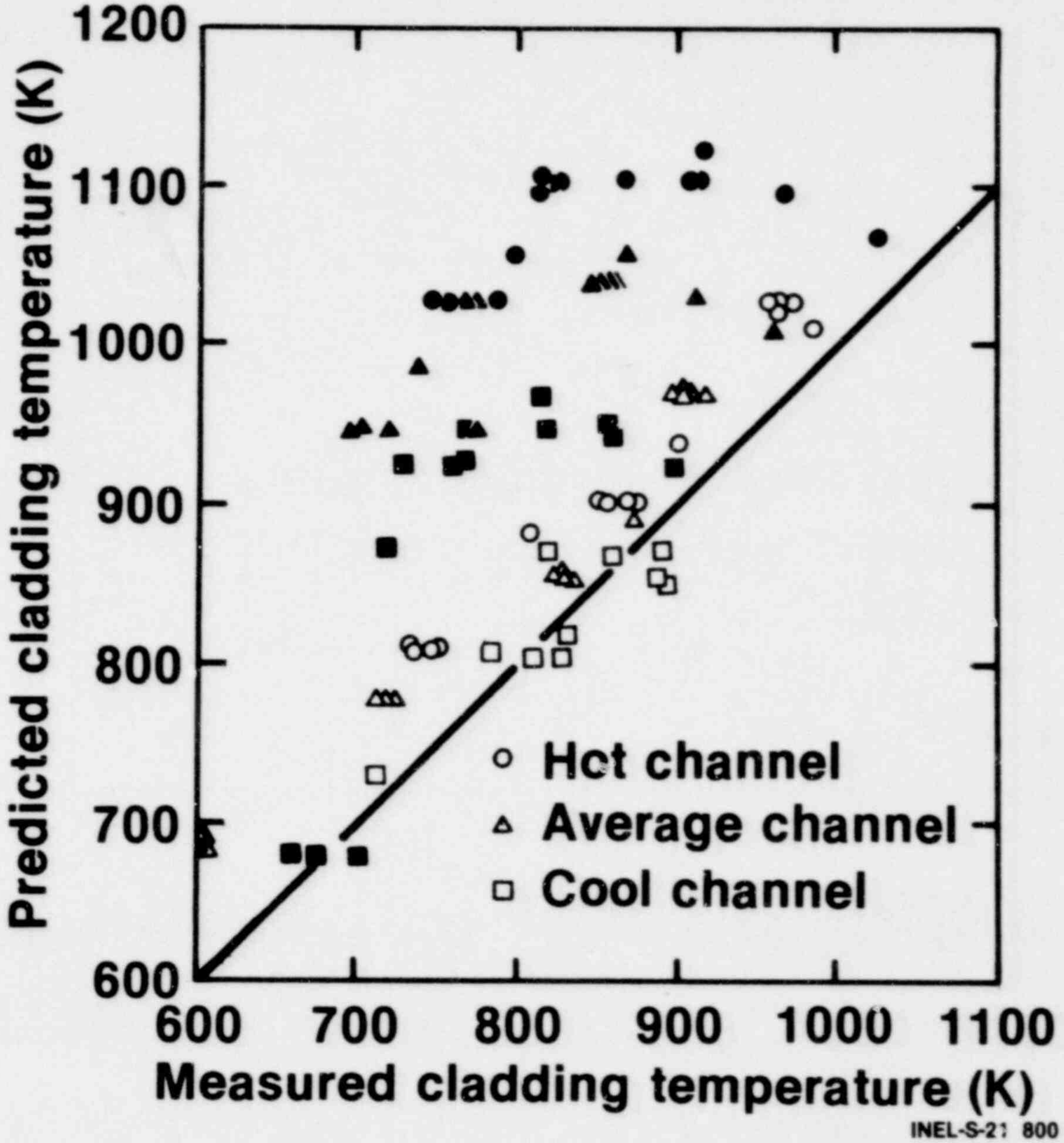
Predicted Maximum Cladding Temperature Compared to Data PKL Test K5A



Reflood Systems Effects Subtasks

Component	Performance Evaluator	Uncertainty or Error
Core	Cladding temperature, upper core	<325
	Lower and middle core	<100 K

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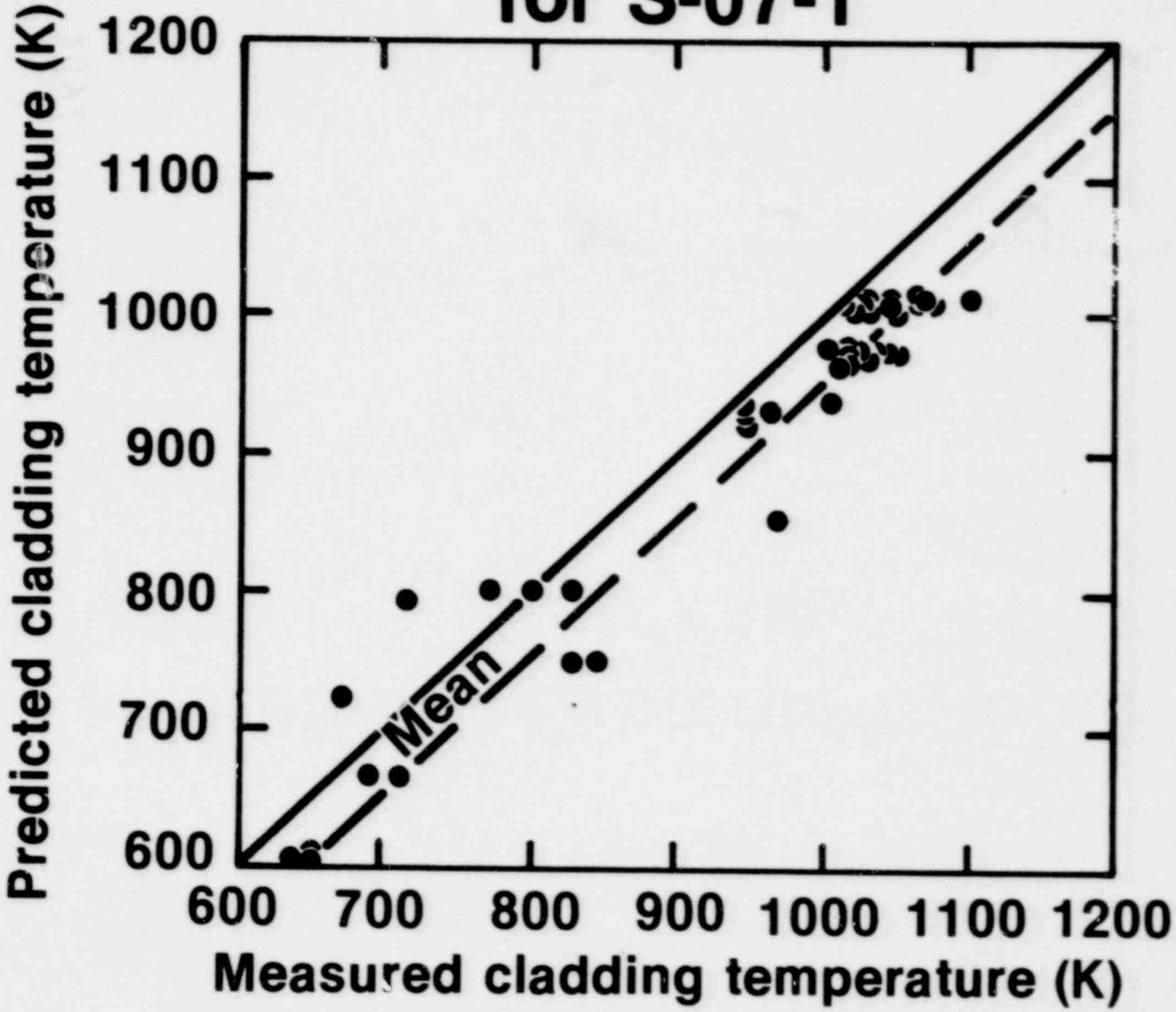
Predicted Maximum Cladding Temperature Compared to Data for S-07-1



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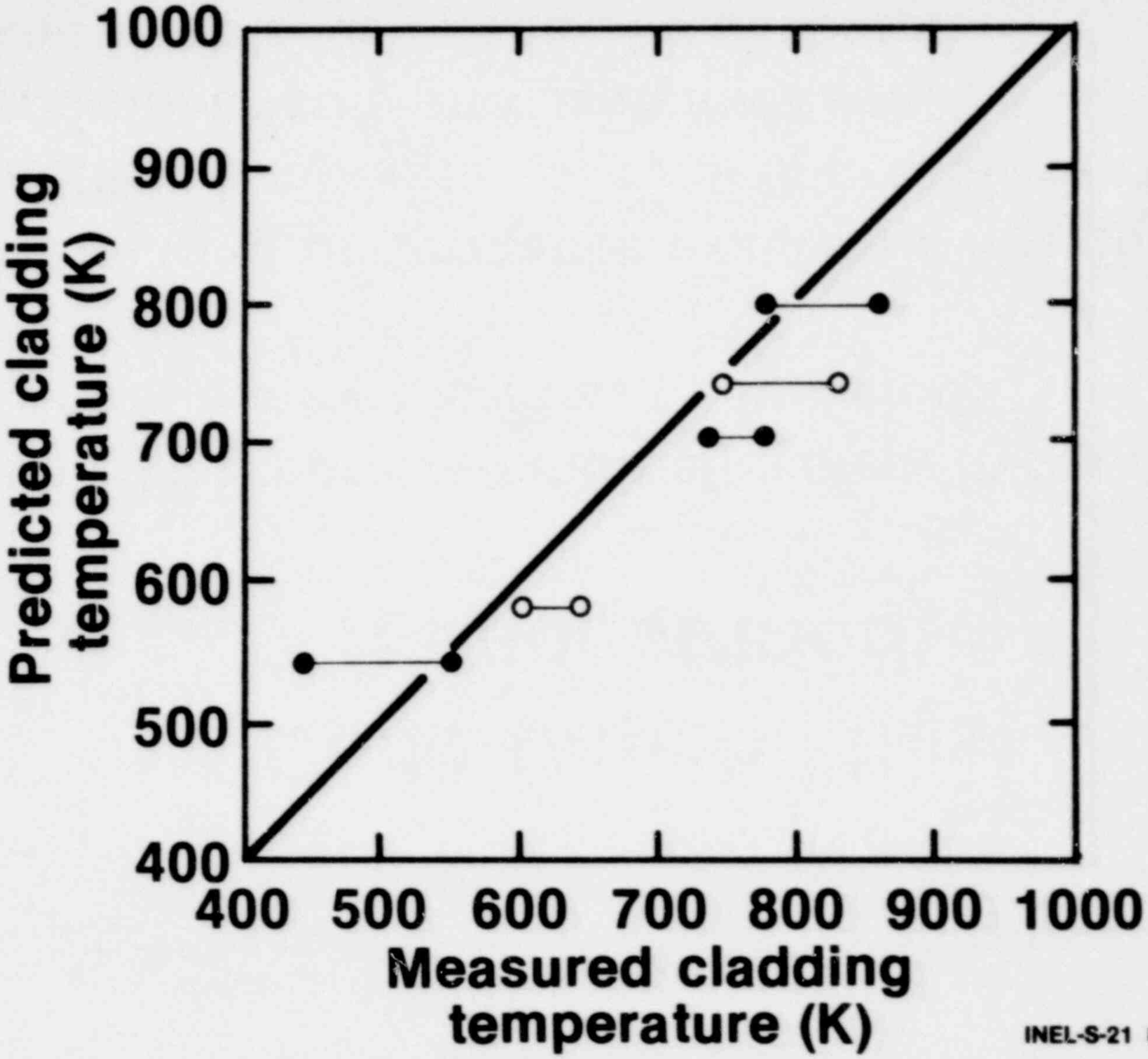
Predicted Maximum Cladding Temperature Compared to Data for Semiscale Mod-3 Test S-07-4



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Code Capabilities Demonstrated

- Analytical representation of system hydraulics is adequate for blowdown and reflood

- Matching of performance evaluators (maximum cladding temperatures, system pressures) for separate-effects and system-effects experiments was generally satisfactory

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Code Deficiencies Demonstrated

- Inadequacies of specific empirical models
  - Entraintment
  - Phase separation

- Code capability to calculate refill period limited by homogeneous, equilibrium assumption

- Need for improved user guidelines
  - Critical flow
  - Reflood heat-transfer/fluid phase relationship

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