RELAP5-3D Developmental Assessment Results

Paul Bayless, INL
Doug Barber, ISL

RELAP5 International User's Seminar
August 11-13, 2009

Idaho National Laboratory

Outline

- **Developmental assessment overview**
- **Assessment results**
- **Future activities**

Developmental Assessment Overview

- 53 cases
  - 17 phenomenological problems
  - 27 separate effects experiments
  - 9 integral effects cases (8 experiments)
- Judgments made on code-to-data comparisons (excellent, reasonable, minimal, insufficient)
- Semi- and nearly-implicit solution schemes
- RELAP5-3D version 2.9.2
- Used automated testing framework in SNAP

Phenomenological Problems

- **Generally simple thought problems that address a single code model**
- **Analytic solutions may be available**
- **Without an analytic solution, highest possible assessment finding is “reasonable”**

Phenomenological Test Cases (1)

Case	Finding
Bubbling steam through liquid	Reasonable
Conduction enclosure steady state	Excellent(1)
Conduction enclosure 1-D transient	Excellent(1)
Conduction enclosure 2-D transient	Excellent(1)
1979 ANS-5.1 decay heat	Excellent(1)
Fill/drain	Excellent(1)
Gravity wave 1-D	Reasonable
Gravity wave 3-D	Reasonable

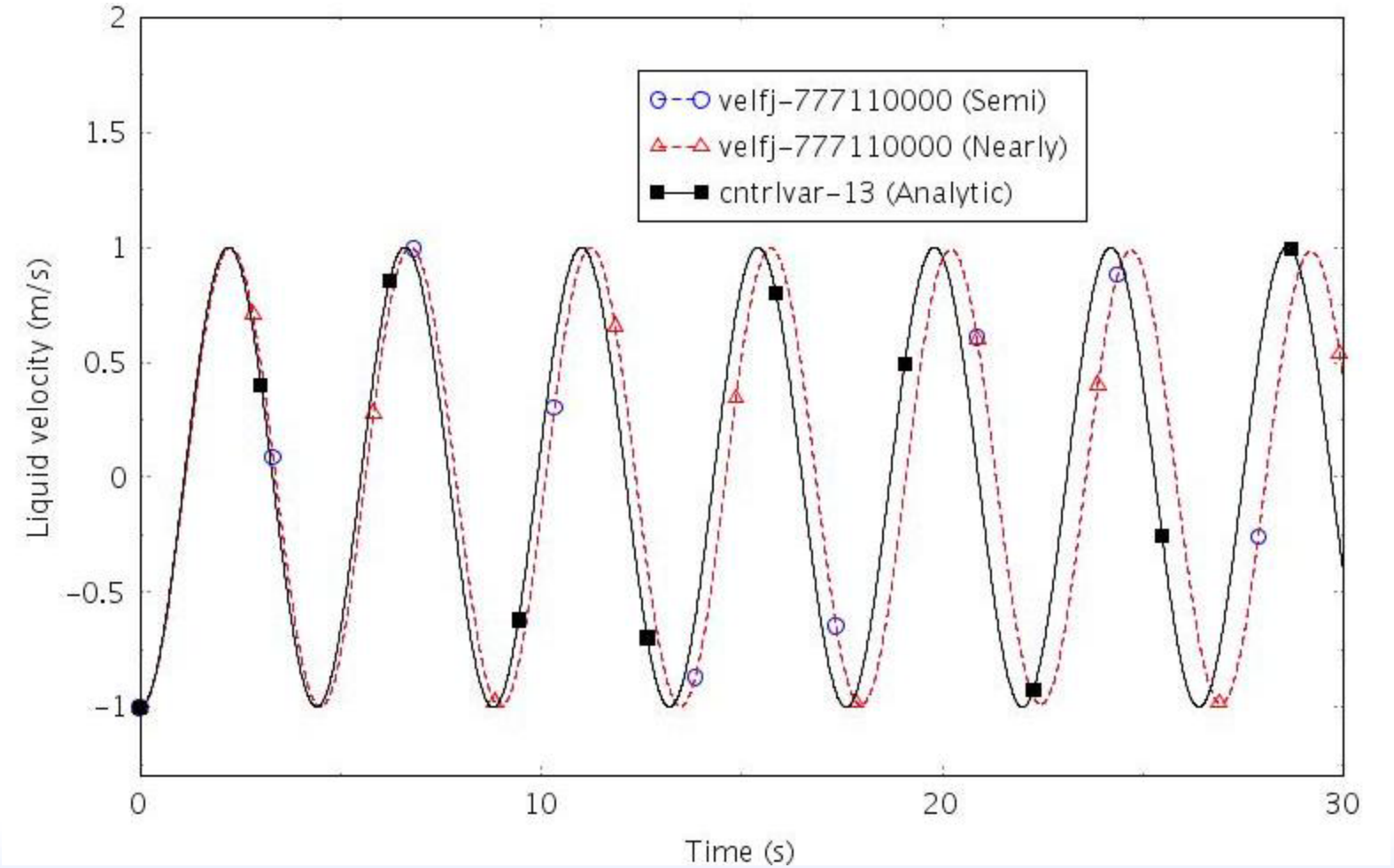
(1) Based on comparison to analytic solution

Phenomenological Test Cases (2)

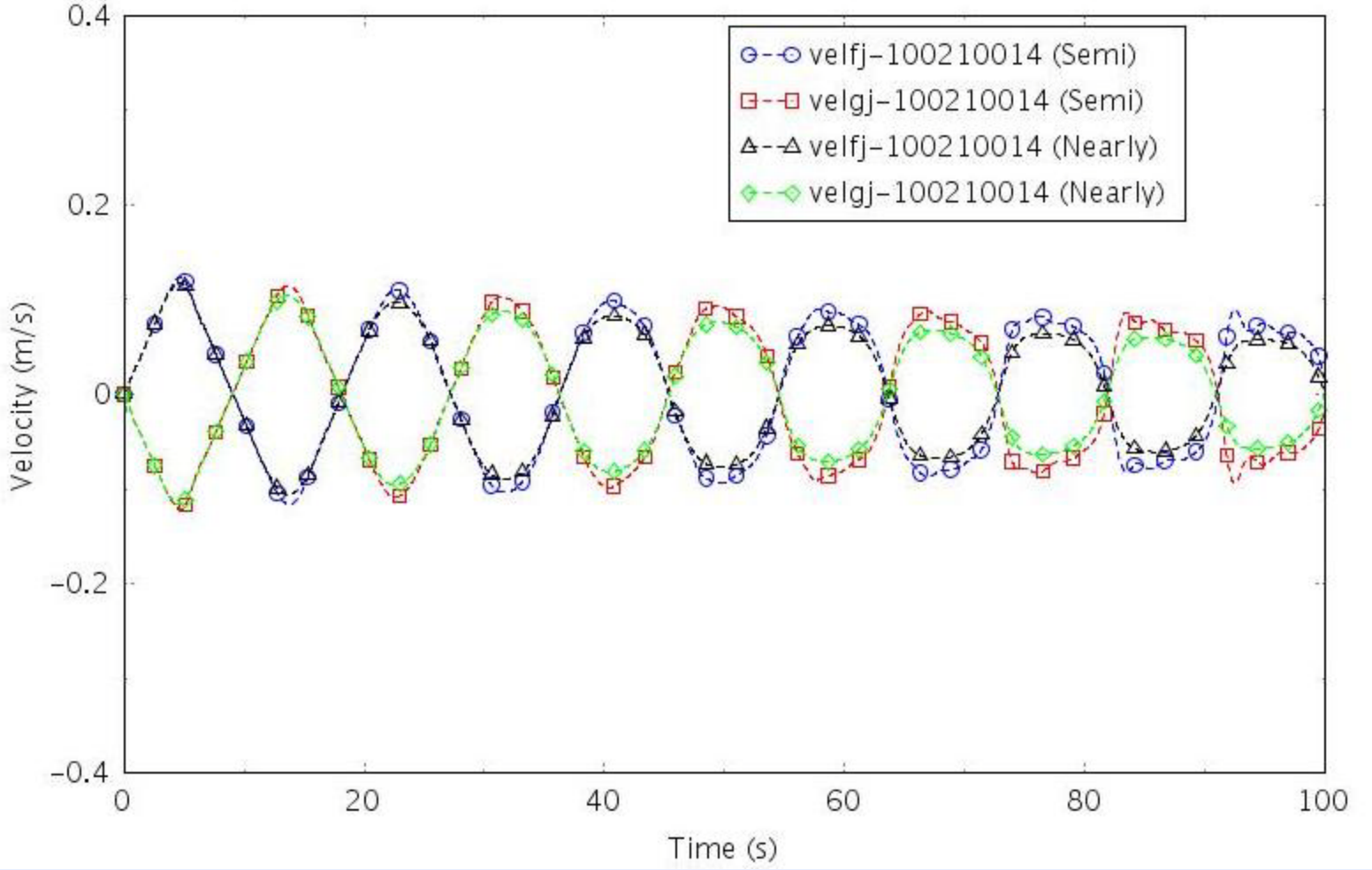
Case	Finding
Manometer	Reasonable
Point kinetics ramp	Excellent(1)
Pryor pressure	Reasonable
Pure radial flow	Excellent(1)
Rigid body rotation	Excellent(1)/Minimal
R-theta symmetric flow	Excellent(1)/Minimal
Water faucet	Excellent(1)
Water over steam 1-D	Reasonable
Water over steam 3-D	Reasonable/Insufficient

(1) Based on comparison to analytic solution

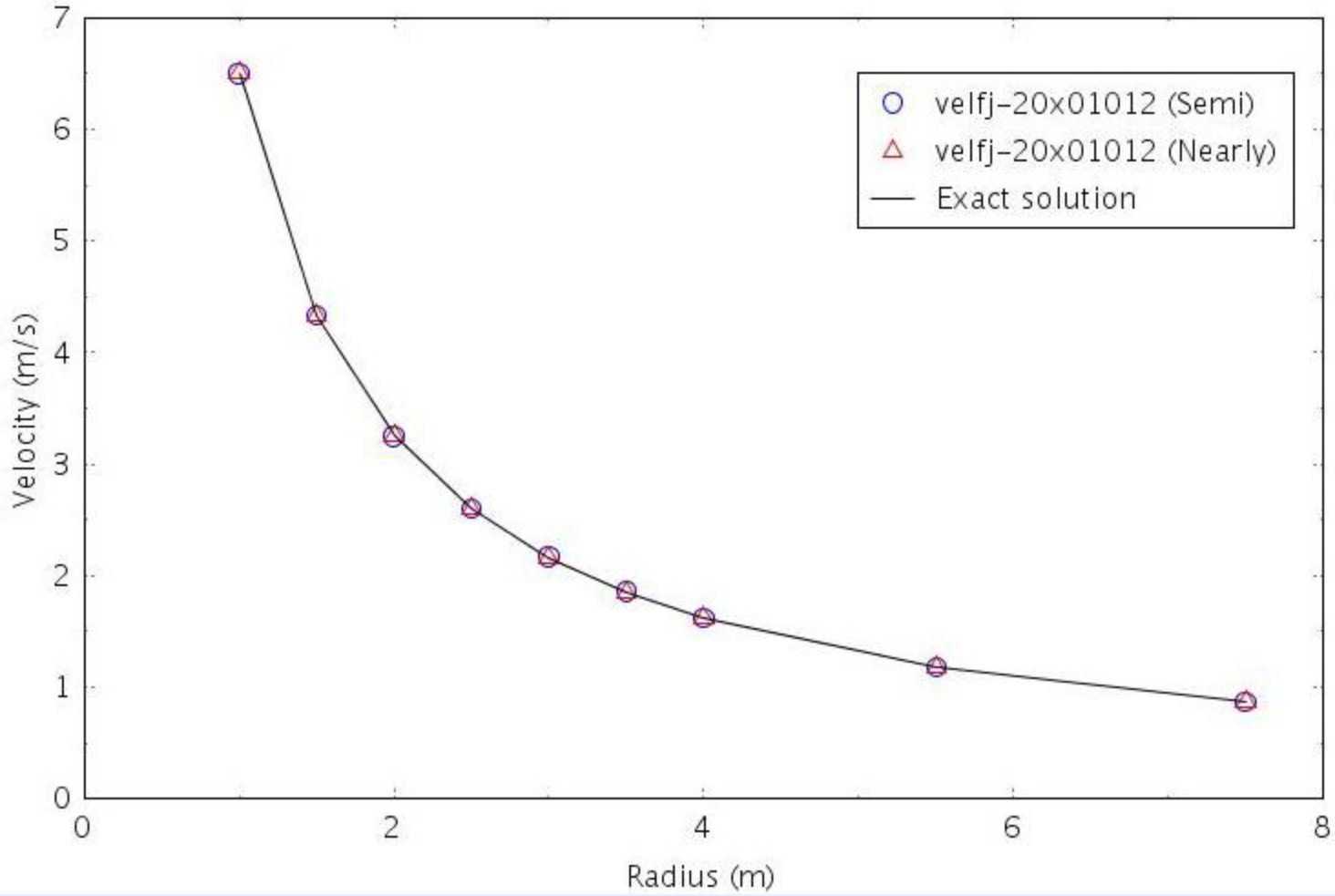
Manometer Problem Liquid Velocity



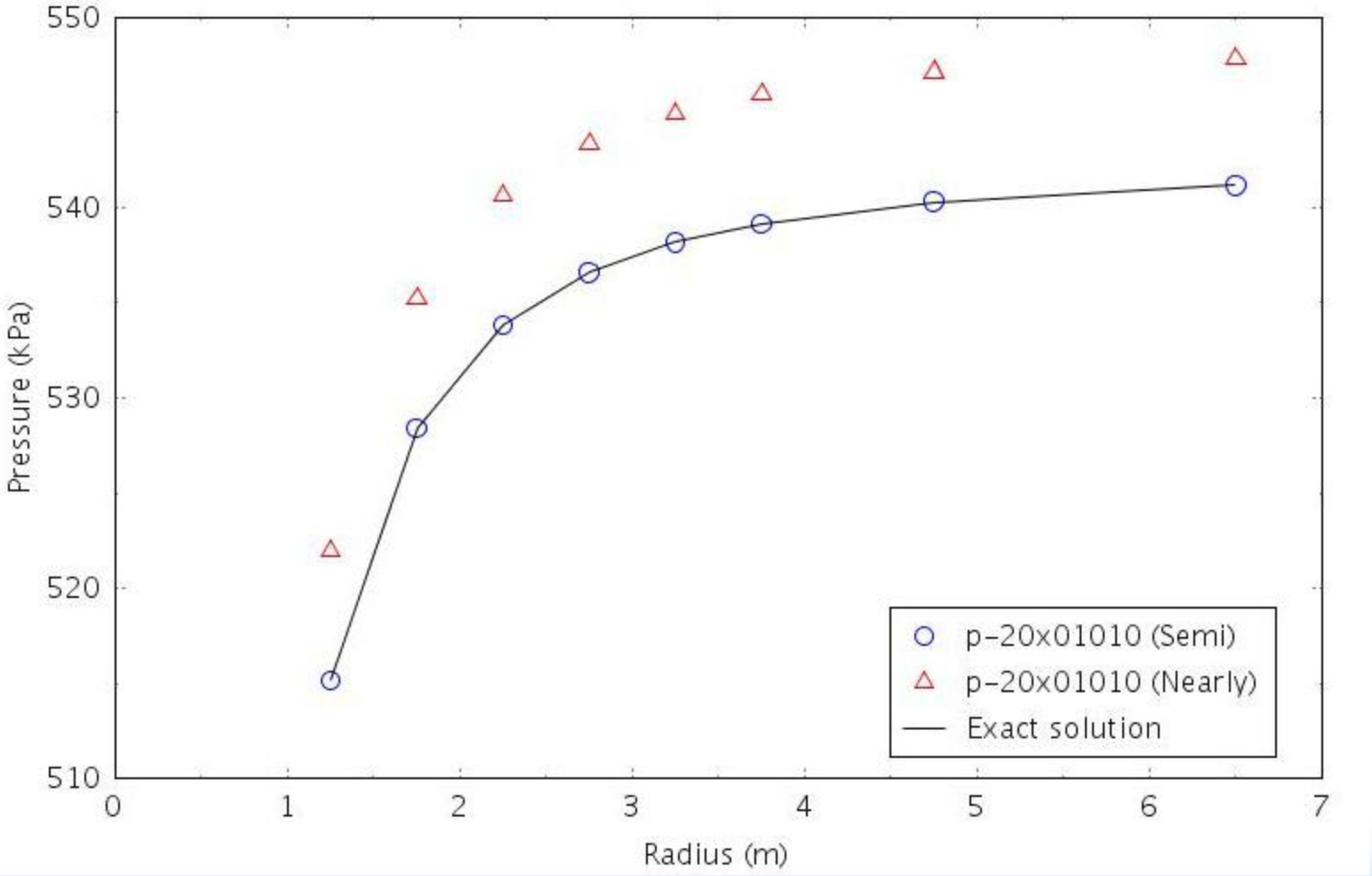
3-D Gravity Wave Phasic Velocities



R-theta Problem Radial Velocities



R-theta Problem Radial Pressures



Separate Effects Experiments (1)

- Bennett heated tube (3) (CHF)
- Christensen (subcooled boiling)
- Dukler-Smith (CCFL)
- Edwards-O'Brien pipe (vapor generation)
- FLECHT SEASET (2) (bundle heat transfer)
- GE jet pump
- GE level swell (2) (two-phase level)
- LOFT (accumulator)
- Marviken (4) (critical flow)

Separate Effects Experiments (2)

- MB2 (steam generator behavior)
- MIT pressurizer
- Moby Dick (critical flow)
- NEPTUNUS (pressurizer)
- Ontario Hydro (two-phase pump)
- ORNL THTF (4) (bundle heat transfer)
- RIT (CHF)
- UPTF (downcomer CCFL)

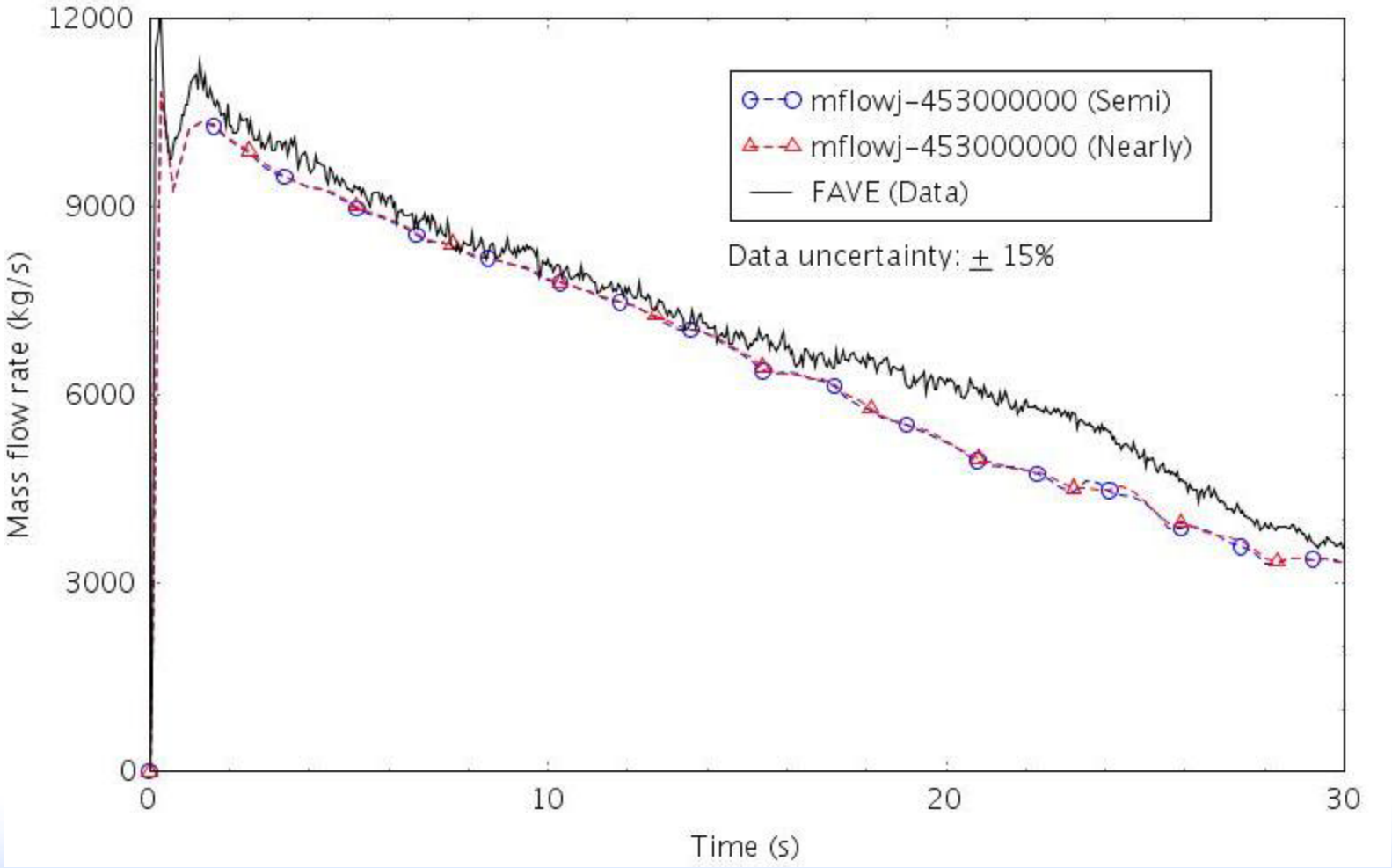
Separate Effects Test Results (1)

Phenomenon	Finding
Critical flow	Excellent (1) Reasonable (5)
Two-phase level/void distribution	Excellent (2) Reasonable (2)
Critical heat flux	Reasonable (8)
Reflood	Reasonable (2)
CCFL	Reasonable (2)
Pressurizer behavior	Excellent (1) Reasonable (1)
Steam generator steady state	Reasonable (1)

Separate Effects Test Results (2)

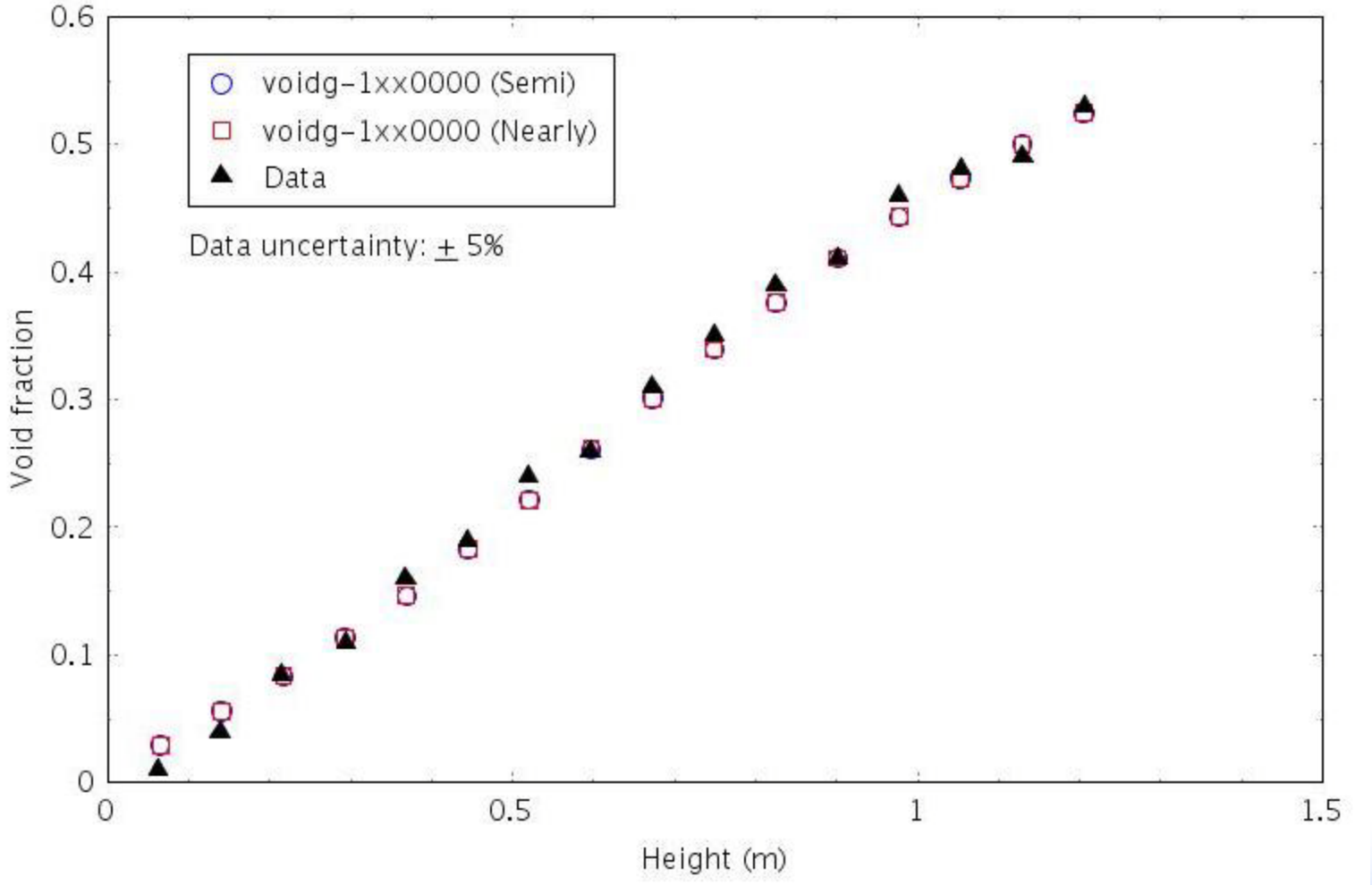
Phenomenon	Finding
Accumulator response	Excellent (1)
Two-phase pump behavior	Reasonable (1)
Jet pump flow	Reasonable (1)
Film boiling heat transfer coefficient	Minimal (3)

Marviken CFT 21 Flow Rate

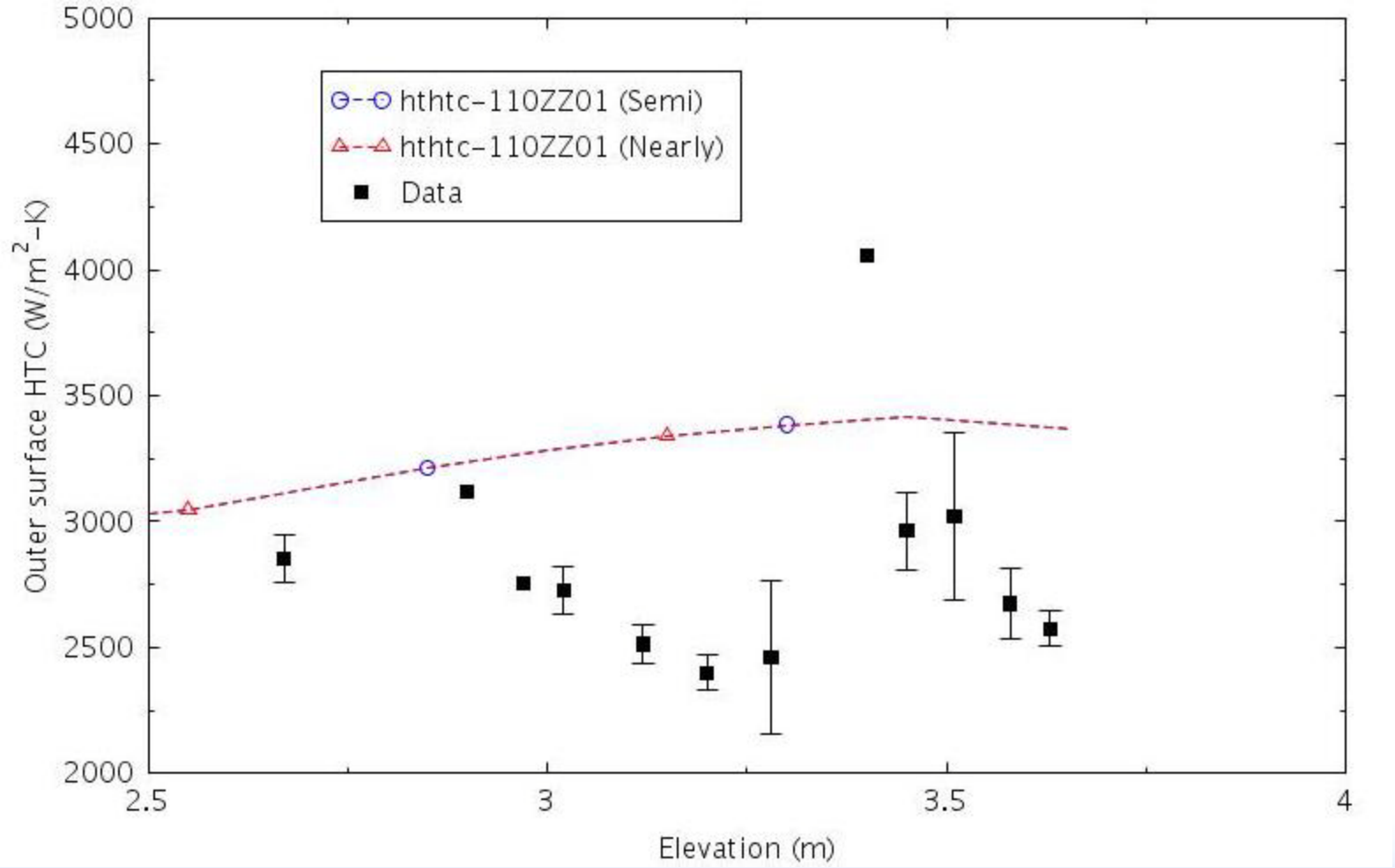


Idaho National Laboratory

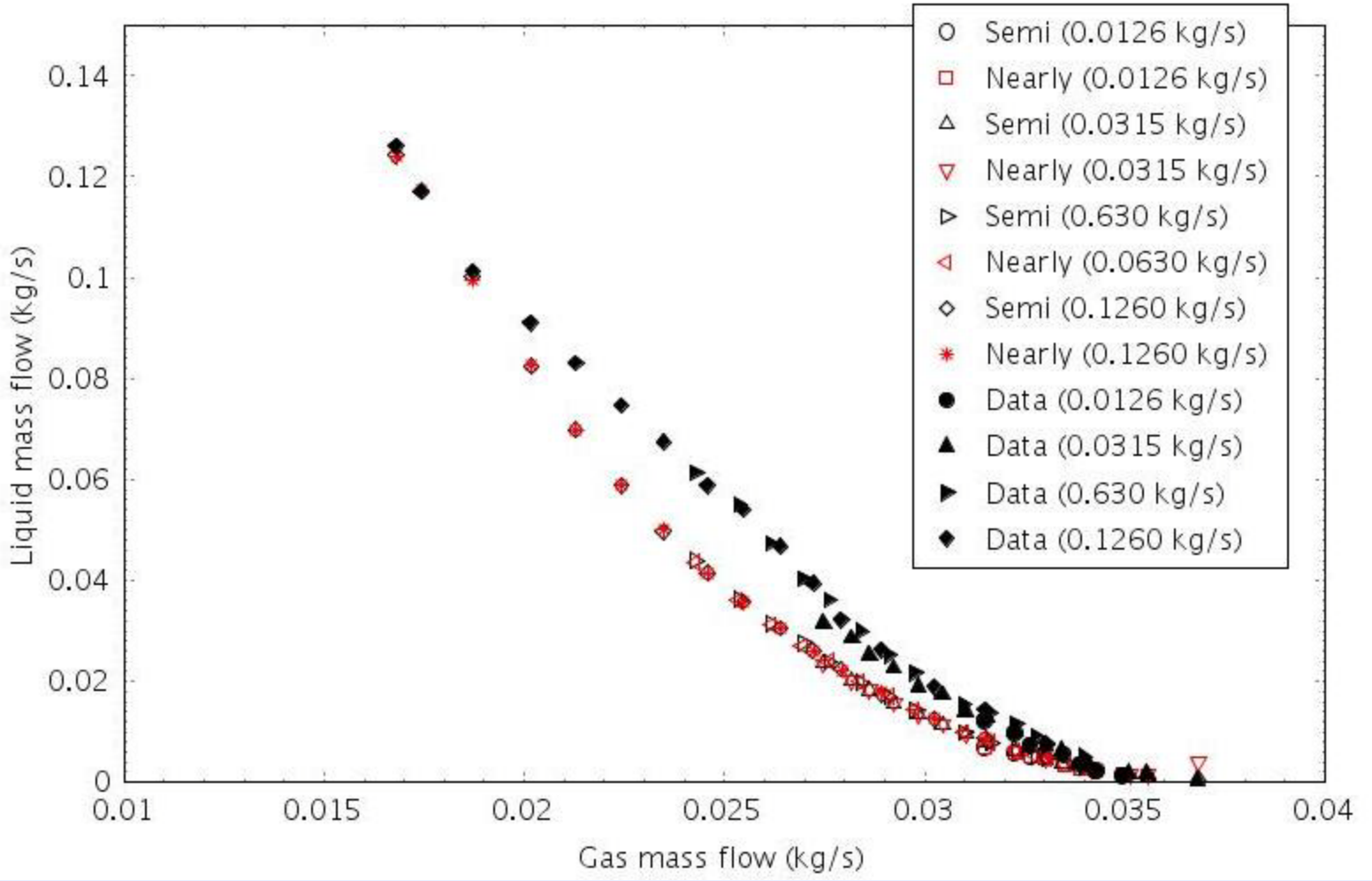
Christensen Test 15 Void Profile



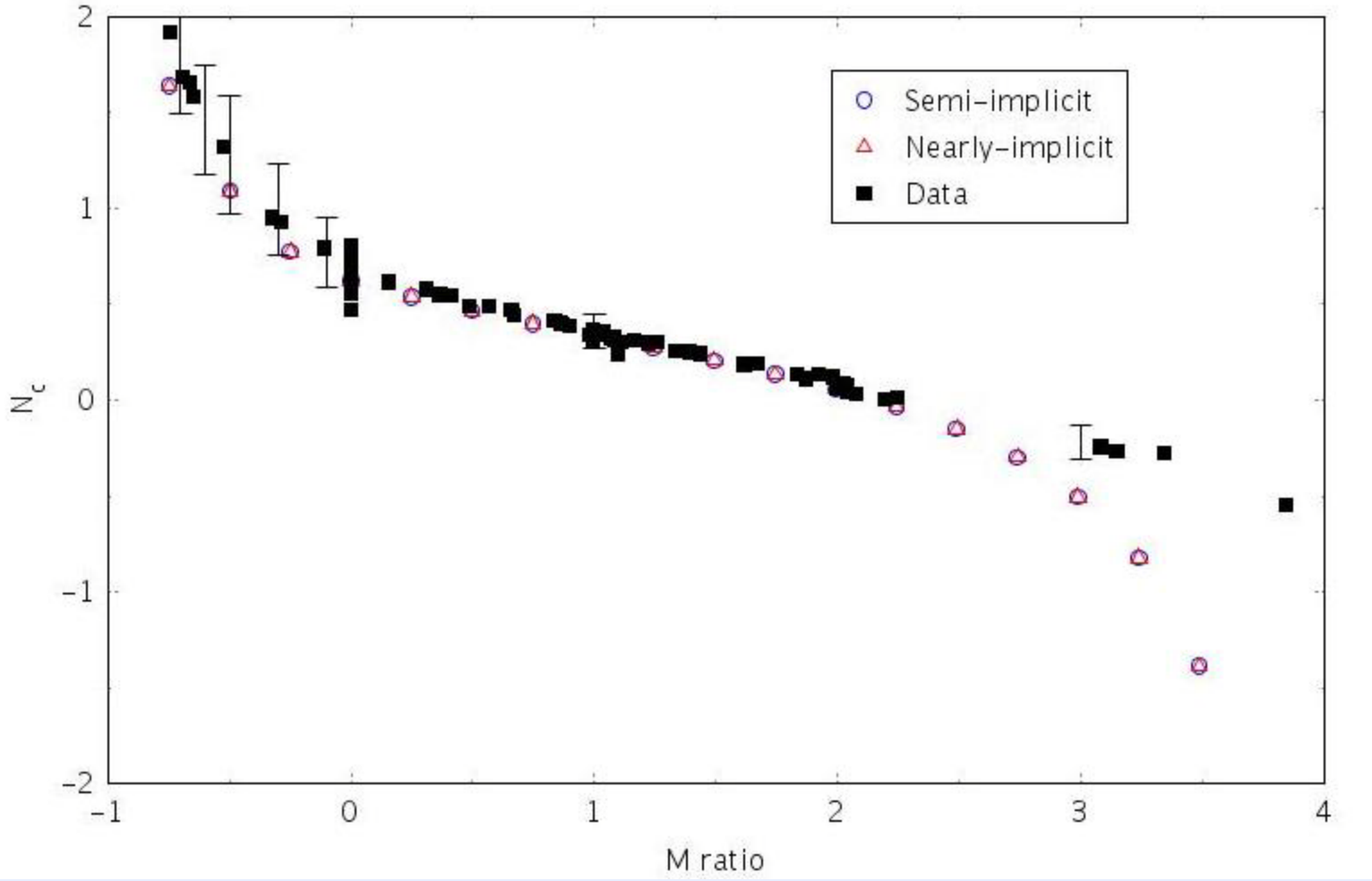
THTF Test 3.07.09N Film Boiling



Dukler-Smith Air-Water CCFL Data



GE 1/6-scale Jet Pump Forward Flow



Integral Effects Cases

- Two small break LOCAs
  - LOFT L3-7
  - ROSA SB-CL-18
- Four natural circulation tests
  - Semiscale NC-1, 2, 3, 10
- Three large break LOCAs
  - LOBI A1-04R
  - LOFT L2-5 (1-D and 3-D models)

LOFT L3-7 1-in. Cold Leg Break

- Most phenomena simulated well
  - Primary coolant system pressure
  - Pressurizer level
  - Temperatures for first 1200 s
  - ECC flow
- Break flow was not well simulated after 400 s
  - Consequent difficulties with cold leg densities, coolant temperatures after 1200 s

ROSA SB-CL-18 5% Cold Leg Break

- Most parameters simulated well
  - Primary and secondary system pressures
  - Loop flow rates
  - Accumulator flow rates
  - Lower core temperatures
- Primary problem was not clearing one loop seal
  - Core level under predicted
  - Length of core uncovery over predicted

Semiscale Natural Circulation Tests

- **Single-phase predictions excellent**
- **Two-phase calculations reasonable at high and intermediate powers, minimal at low power**
- **Reflux condenser mode predicted reasonably at high power and system inventory less than 67%**
- **Flow rates well predicted with steam generator heat transfer area >50%, over predicted with lower effective surface areas**

LOBI Test A1-04R Large Break

- Excellent agreement for
  - Primary system pressure
  - Heater rod temperatures in lower core in nucleate boiling region
- Reasonable agreement for
  - Loop mass flow
  - Heater rod temperatures in upper core in film boiling region
- Minimal agreement for heater rod temperatures in mid-core in transition boiling region

LOFT Experiment L2-5 LBLOCA (1-D)

- Acceptable simulations of
  - Primary and secondary system pressures
  - Loop flow rates and broken loop densities
  - Coolant temperatures
  - Fuel rod temperatures
  - ECC flows
  - Bottom-up/top-down quench
- Minimal simulation of intact loop densities (over predicted)

LOFT Experiment L2-5 LBLOCA (3-D)

- Most results the same as for the 1-D case
- Nearly-implicit calculation had a water property failure that could not be worked around
- Three-dimensional effects more pronounced in the experiment than in the calculation
  - Radial temperature variations showed correct trends
  - Almost no variation in azimuthal temperatures

Notable Deficiency

- **Multi-dimensional hydrodynamic component with the nearly-implicit solution scheme**
  - **Incorrect pressure distributions with two-dimensional flows**
  - **Water property failures**
  - **Symptoms known, but root cause undetermined**
  - **Semi-implicit calculations are fine**

Future Activities

- **Results from the developmental assessment will be documented in Volume III of the RELAP5-3D code manual**
- **Efforts to automate the process should simplify the process of adding new cases if desired**
- **Expectation is to update the assessment with the ~annual release of major code versions**