RELAP5-3D Validation Using MB-2 Prototypical Steam Generator Steady State Data

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Overview:

* Context for Effort within Graduate Course Series at UTNE
- Scale Model Boiler (MB-2) Test Overview
- RELAP5-3D System Model
- Prior Simulation Results Using Mod 3.2
- RELAP5-3D versus Mod 3.2.
- Parametric Variations Pertaining to Predicted Limit Cycle
- RELAP5-3D versus Data
- Conclusions and Suggestions for Future Work

Context for Validations Effort:

*UTNE Offers a Two Course Series in Thermal-Fluids Related to Reactor Operation and Safety

*First Course is Extension of Undergraduate Thermal-Science with Turbulence, Integral Transport and Two-Phase Flow/Heat Transfer

*Second Course Extends Integral Transport to Two-Fluid Model and Introduces Code Development and Numerical Methods

*Second Course Class Project Usually Involves using R5 to Evaluate Thermal Limits in a Single Heated Channel (Near-Steady Evaluation)

Expectations and Anxiety:

*The Relationship Between Experiments, Data, Academic Models and Models as Implemented in Code is Examined in the Second Course.
*Most Models Apply over Finite Domains, Requiring Interpolation Between Models in Multi-Dimensional State Space
*Input Requirements are Complex, even for Simple Systems
*Some Independent Method to Create an Expectation is Prudent before using a Tool Like RELAP5
*Second Course Normally Used a “Hand” Calculation to Evaluate Thermal Limits in Channel Prior to Running RELAP5.

Validation Effort in Spring 2003 NE 512 Course:

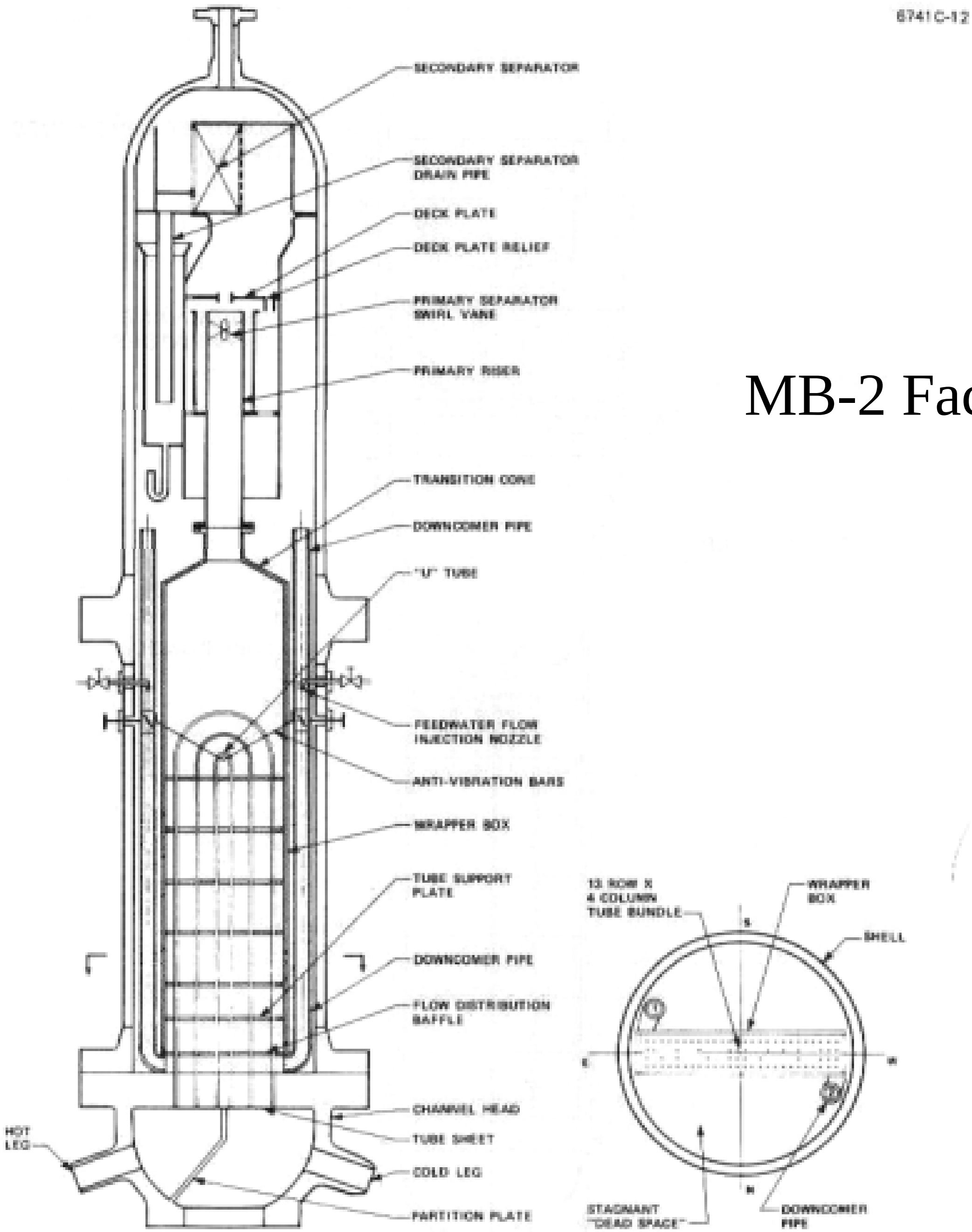
*INEEL Suggested to Evaluate Model Boiler 2 (MB-2) Steady-State Data from NRC Sponsored Tests

*MB-2 Data Used in Previous RELAP5-Mod 3.2 Validation (Rex Shumway, 1995)

*A Limit Cycle Predicted by Mod 3.2 Complicated Simulation of Steady State

*MB-2 Data Were Steady, Westinghouse Tests Prior to NRC Sponsored Tests Evaluated Boiler Stability Limits (Mike Young, 2003)

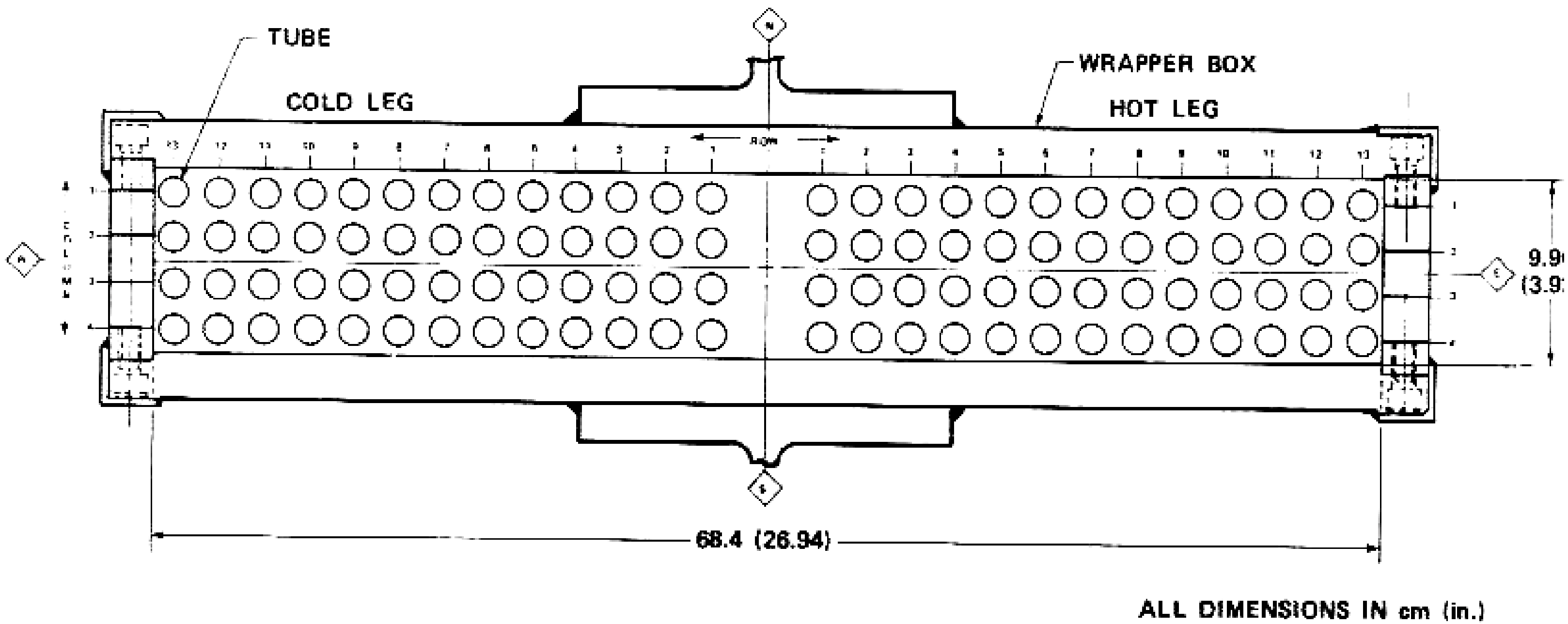
MB-2 Facility



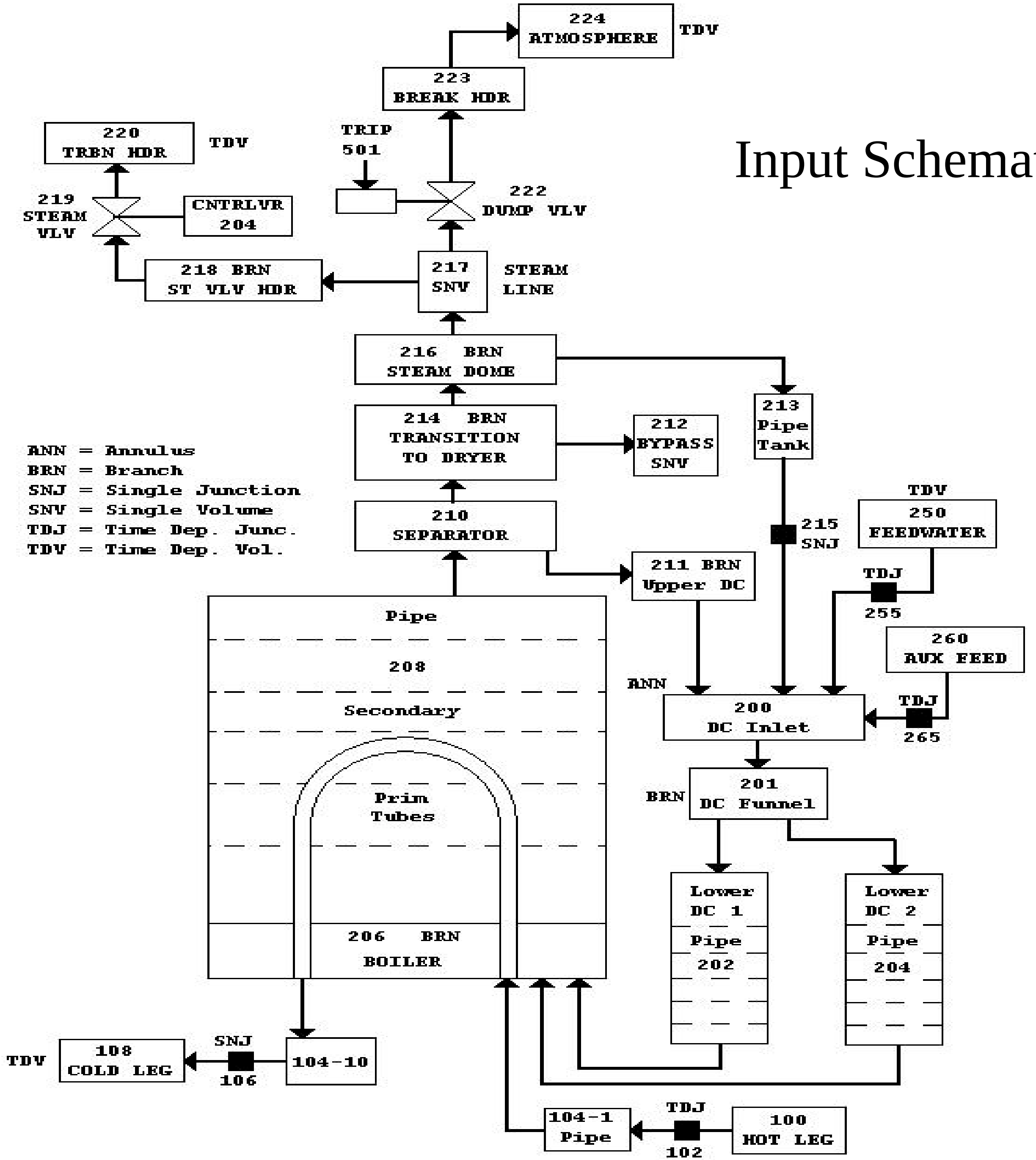
	Model Boiler 2 (MB-2)	Model F S.G.	Ratio of MB-2/S.G.F
Number of U – Tubes	52	5,646	0.00921
Tube Outer Diameter (cm)	1.75	1.75	1.0
Tube Inner Diameter (cm)	1.54	1.54	1.0
Square Pitch (cm)	423	2.49	1.0
Pitch to Diameter Ratio	1.423	1.423	1.0
Tube Height (m)	7.03	8.64	0.814
Primary Tube Volume (m^3)	0.139	18.41	0.00755
Secondary Bundle Volume	0.283	44.88	0.0063
Secondary Volume to Primary Volume Ratio	2.036	2.437	0.835

Scale of MB-2 to Model F Generator

Cross-section of Wrapper Box and Generator Tubes

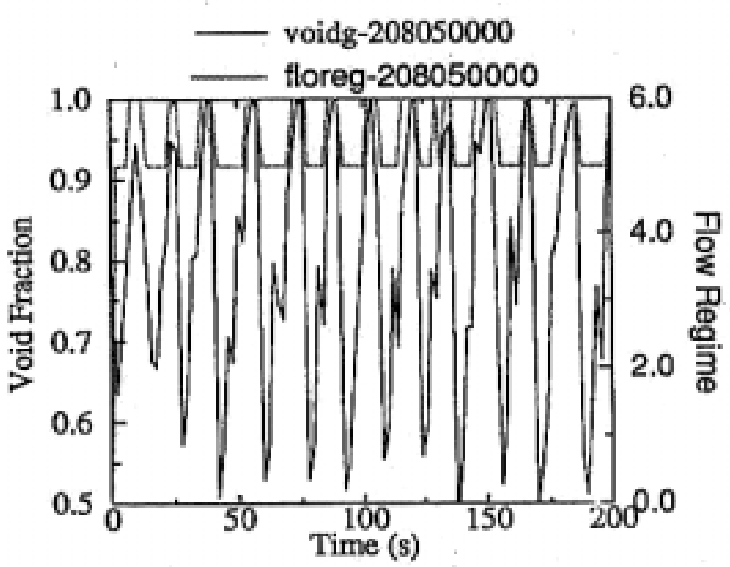


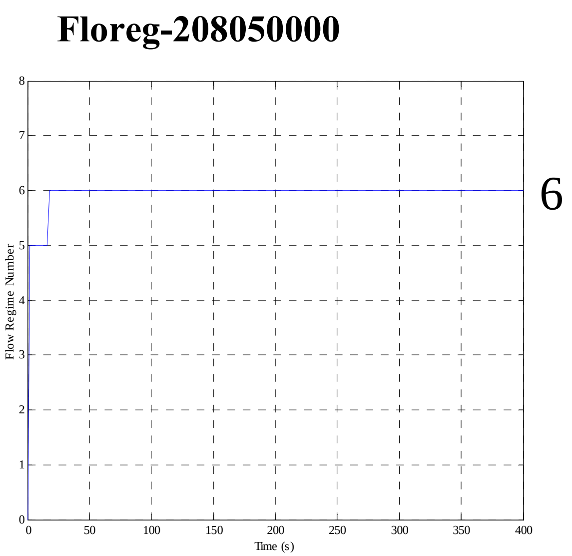
Input Schematic



MB-2 Test 1712 Inital Conditions

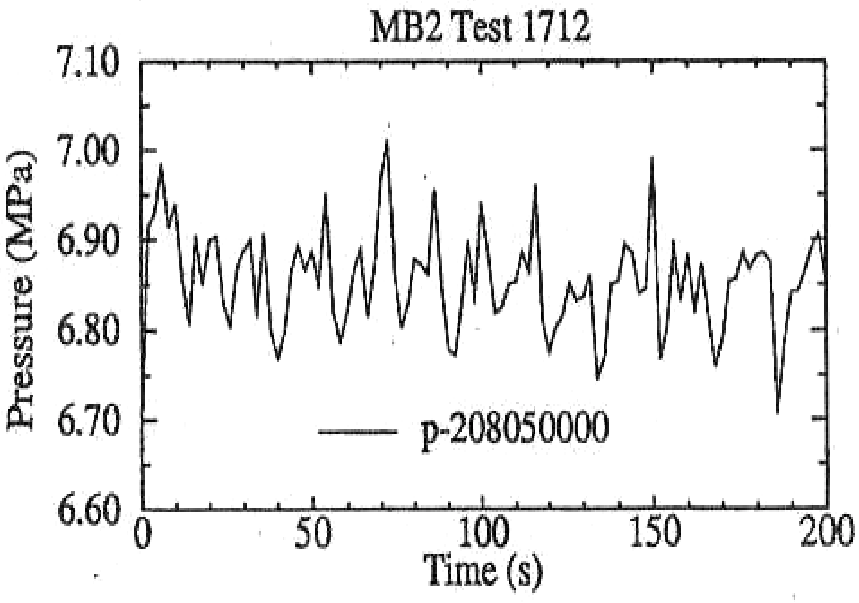
Plant Parameter	**Initial Condition Value**
Primary system pressure (MPa)	15.51
Primary fluid T_{hot} (°C)	325
Primary fluid mass flow rate (kg/s)	41.3
Secondary side pressure (MPa)	6.87
Feedwater temperature (°C)	225
Secondary water level from top of tubesheet (m)	11.18

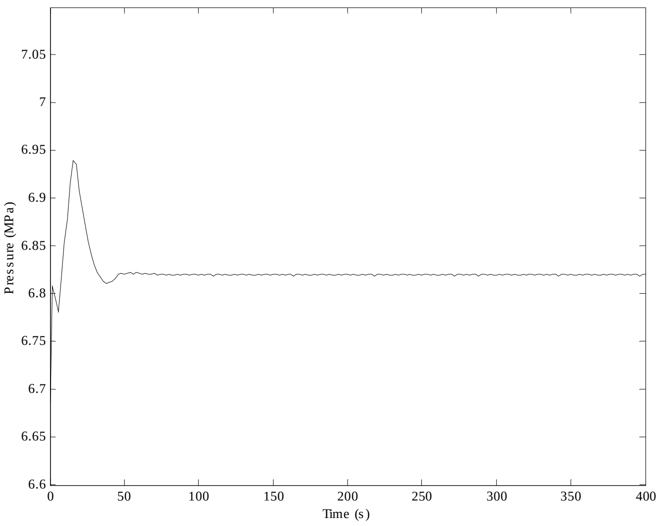




Mod 3.2, (Shumway)

RELAP5-3D





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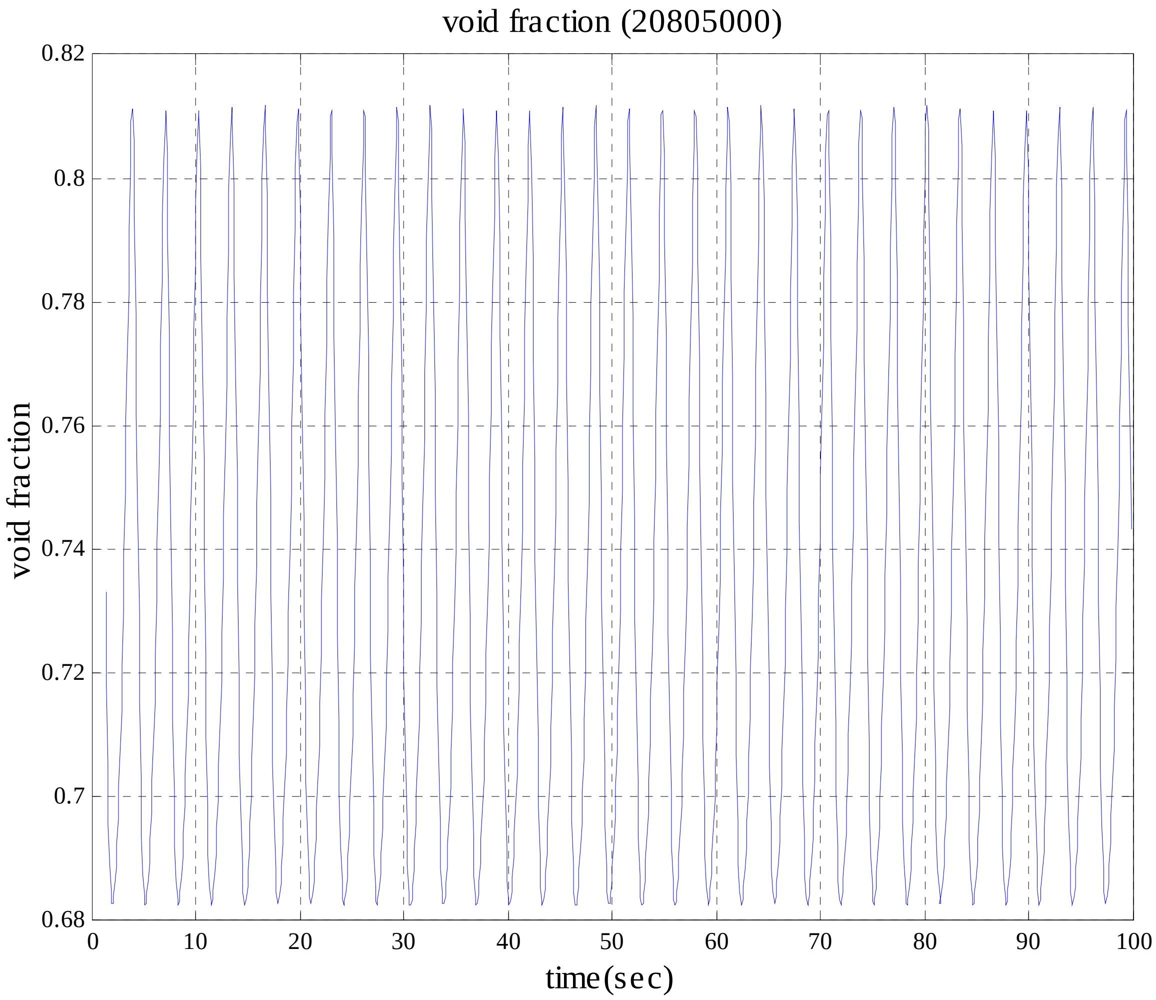
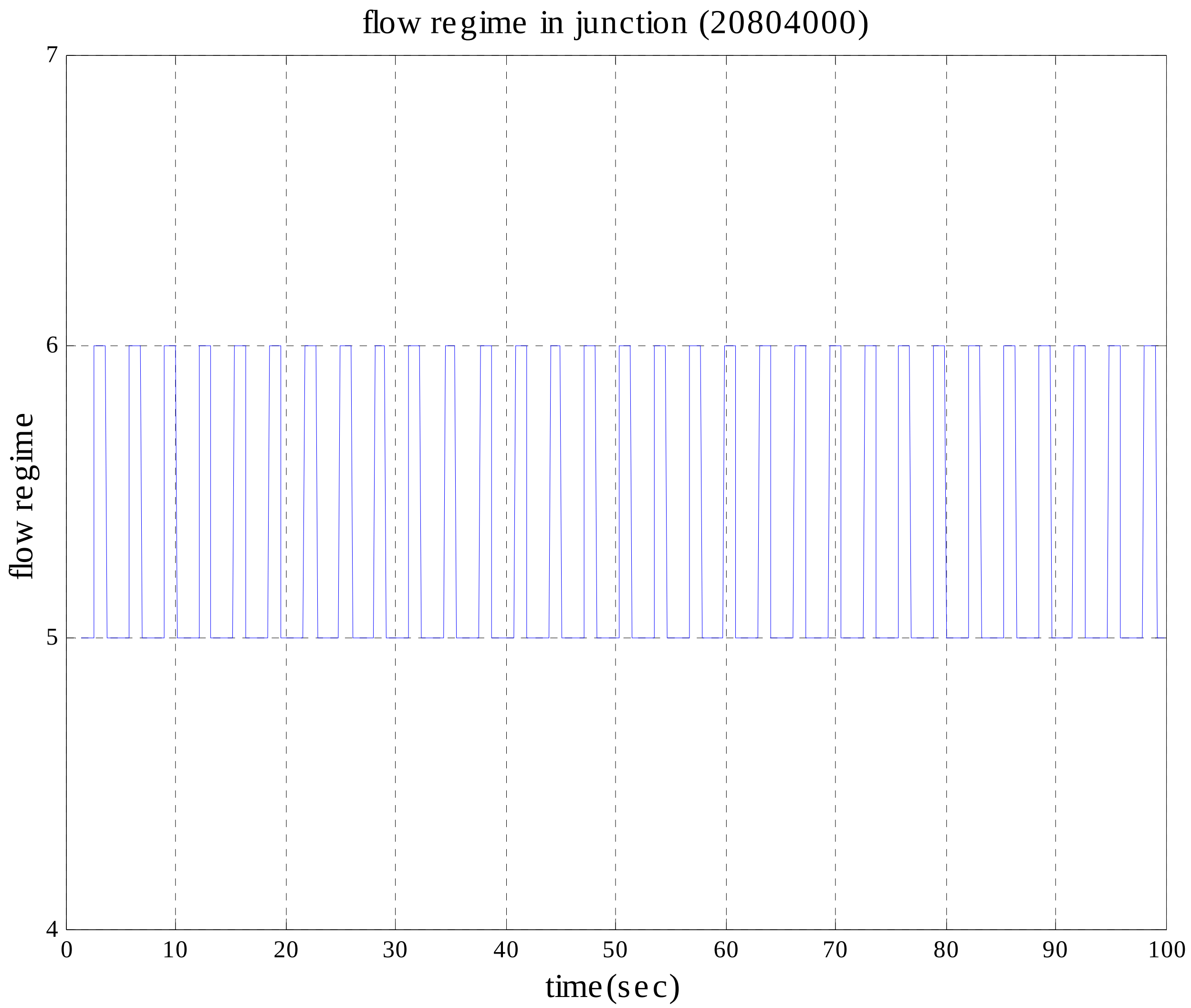
Mod 3.2 (Shumway) RELAP5-3D

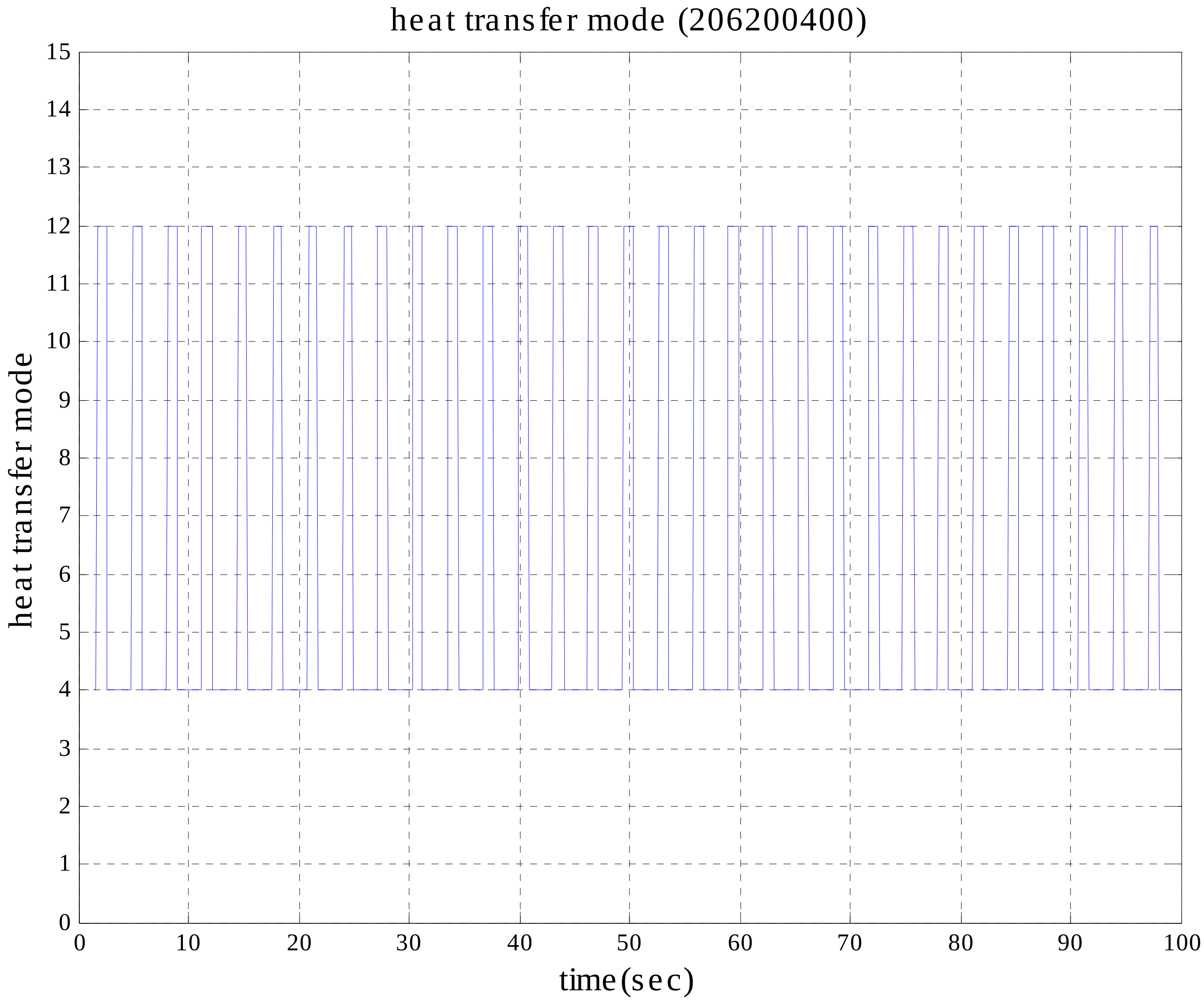
Same Pressure Scale in Both Plots.



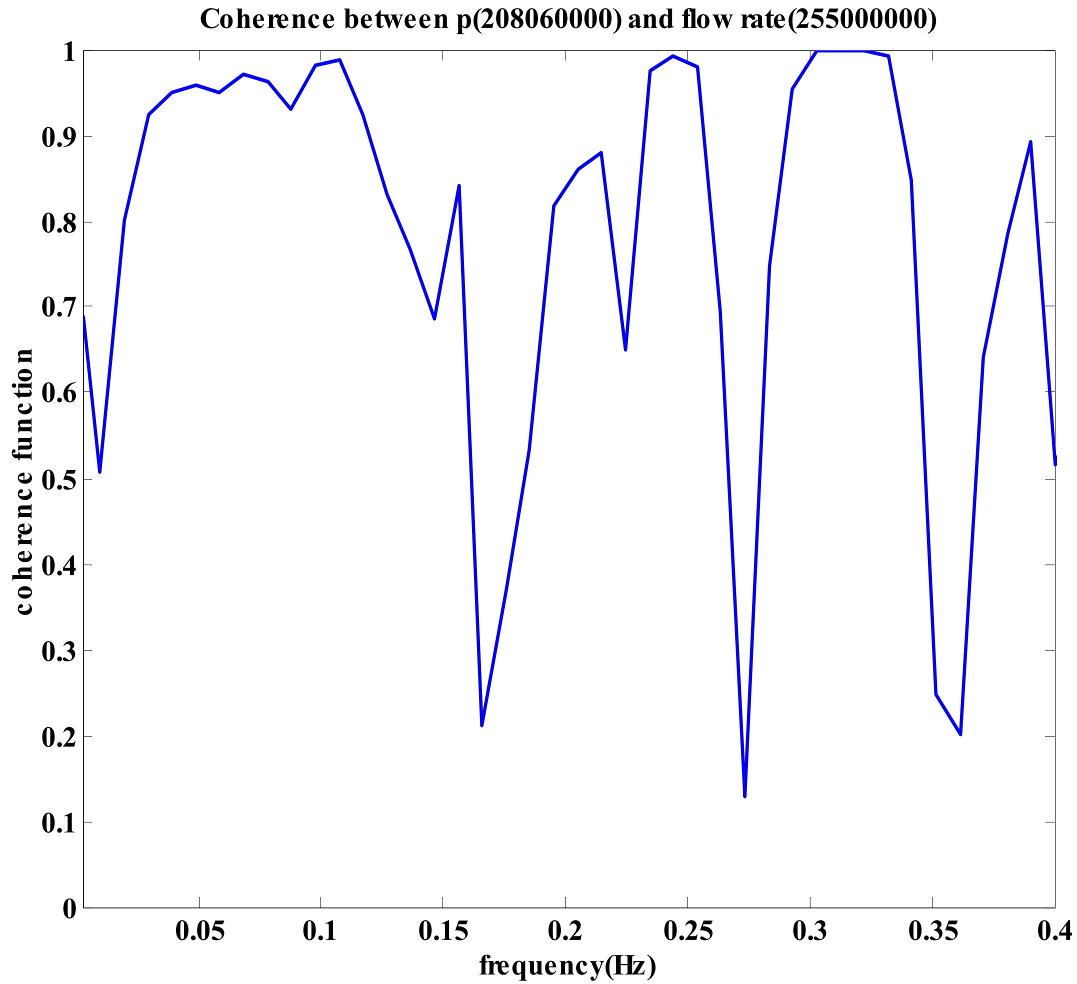
Limit Cycle Still Evident, but Amplitude Lower than Mod 3.2 Simulation Results.



Flow Regime Switching Found One Cell Upstream in Secondary



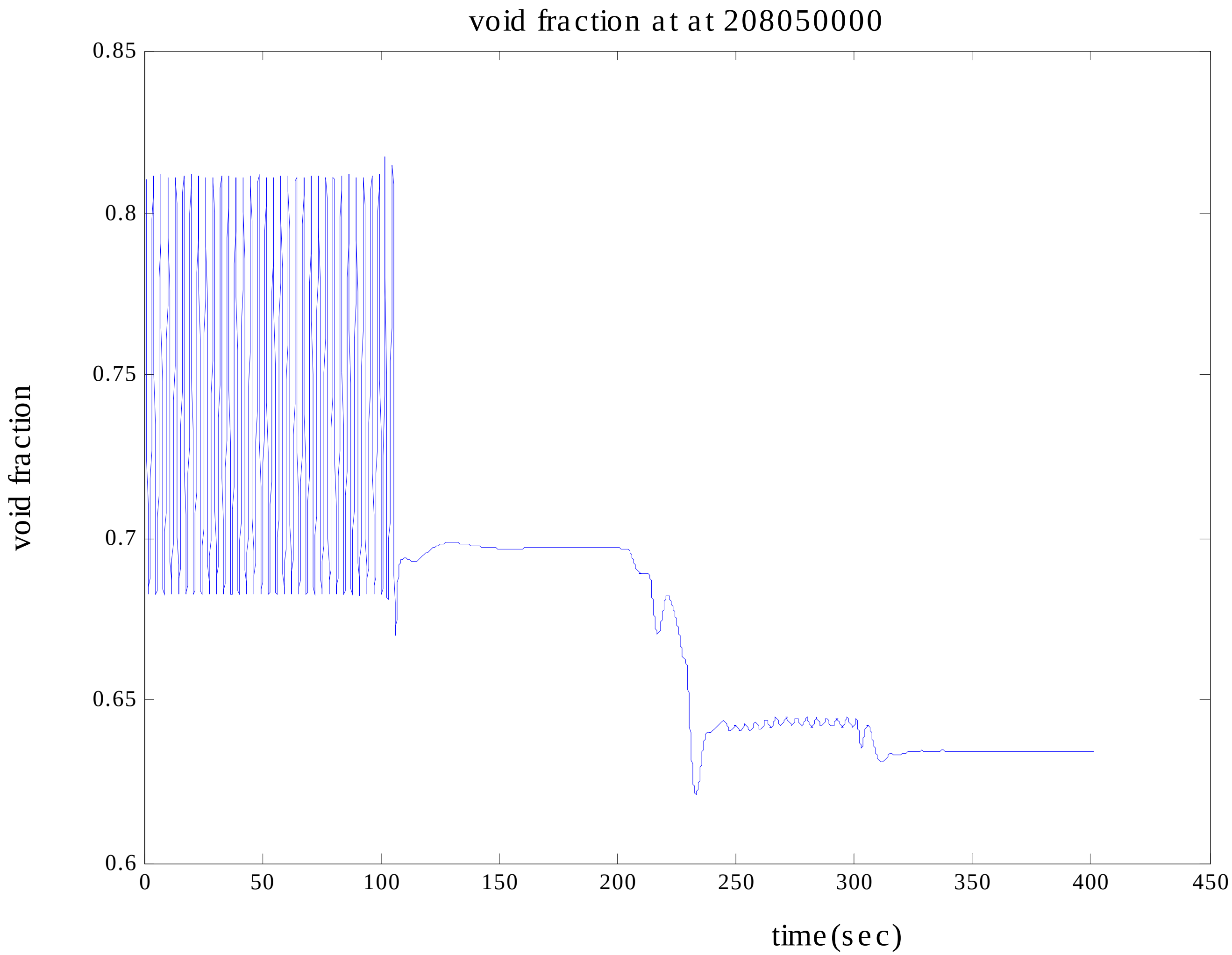
Pressure Variations Cause HT Mode Switch from Evaporation/ Boiling to Condensation



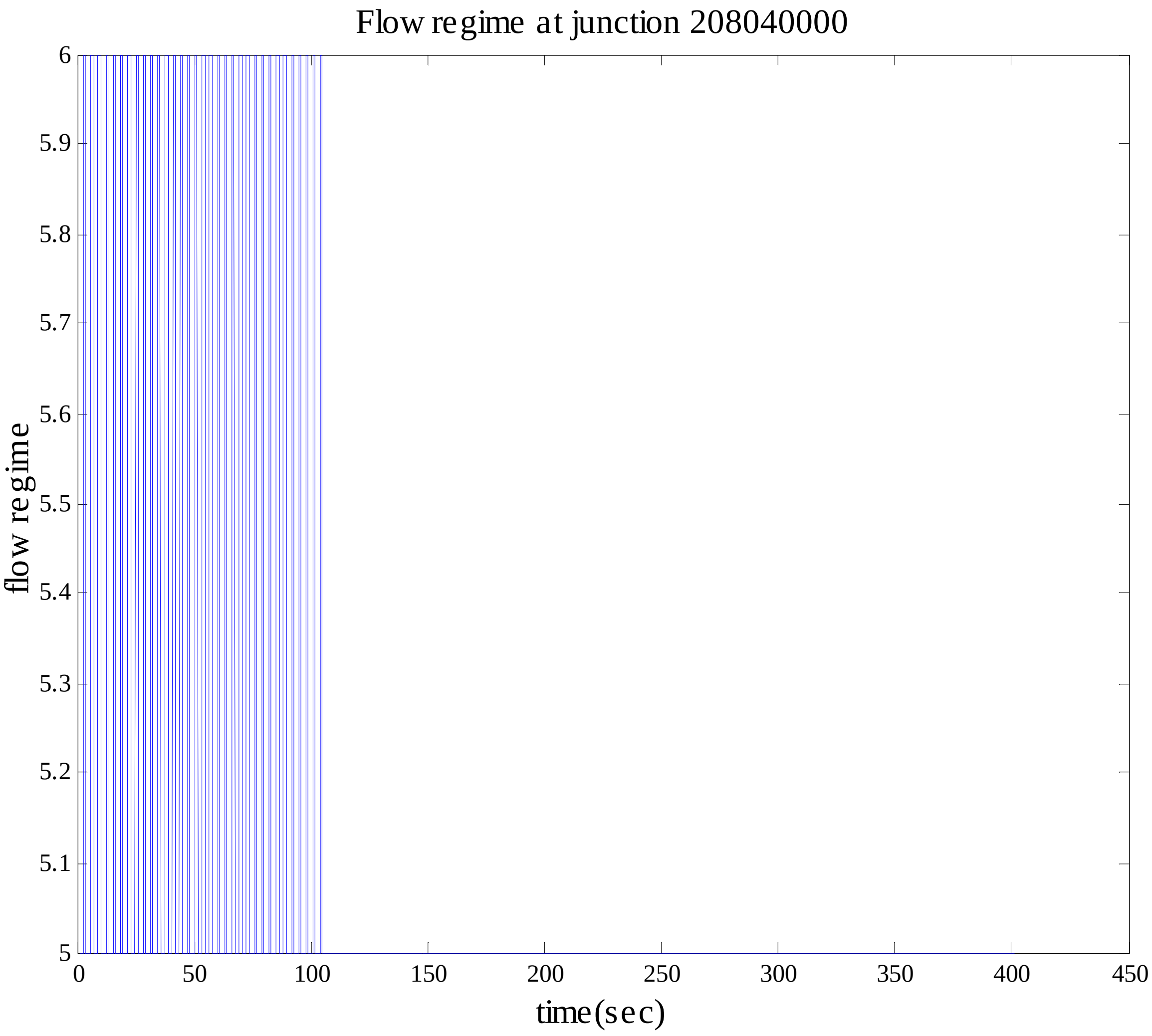
Typical Coherence Evaluation to Ascertain Related Parameters

Input for Hot Leg Inlet Temperature Sensitivity Study

Time (seconds)	Pressure (psia)	Temperature (^oF)
0.0	2250.0	616.4
100.0	2250.0	616.4
101.0	2250.0	611.0
200.0	2250.0	611.0
201.0	2250.0	610.0
300.0	2250.0	610.0
301.0	2250.0	609.0
400.0	2250.0	609.0



Void Response to Inlet Temperature Step Decline



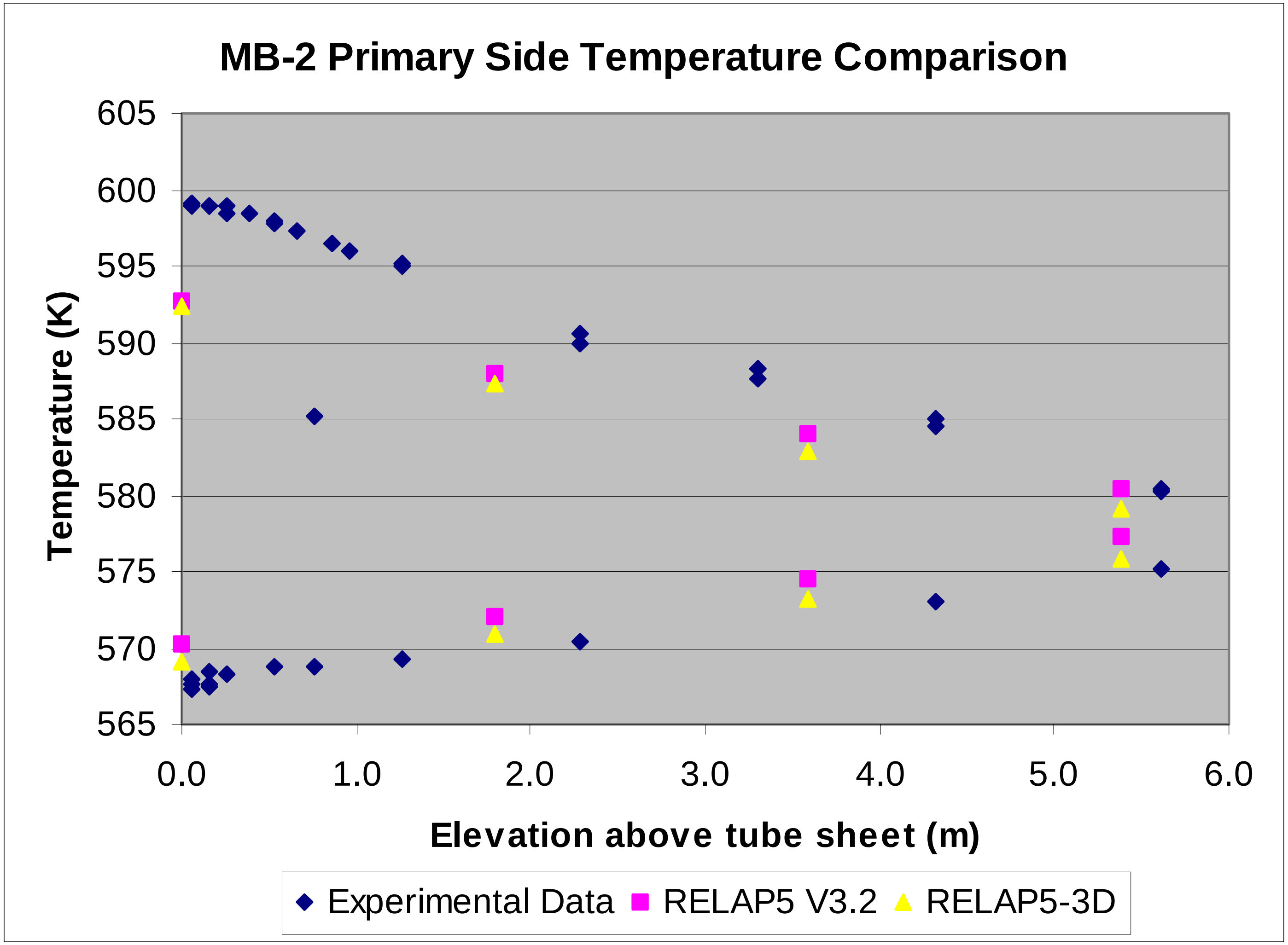
Flow Regime Response to Inlet Temp. Step Decline

Feedwater and Recirculation Sensitivity Study

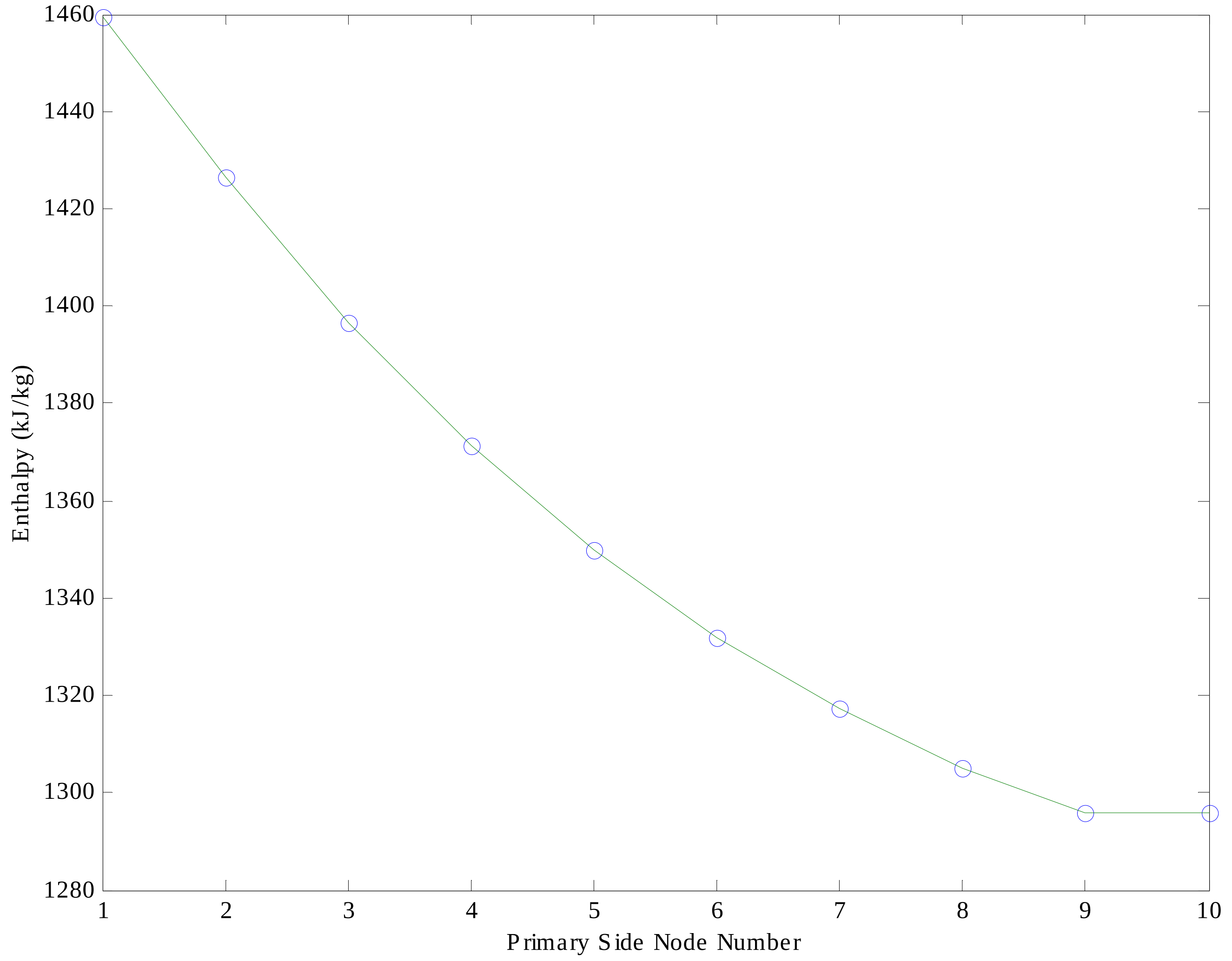
*Isolation of Feedwater Flowrate from the Control (Set to Constant Value) Reduced Limit Cycle Amplitude

*Isolation of Recirculation Flowrate (Set to Constant Value) Also Reduced Limit Cycle Amplitude

*Isolation of Both Feedwater and Recirculation Flow (Set Secondary inlet Flow to Constant) ended the Limit Cycle



RELAP5 Versus MB-2 Primary Temperature Data



Enthalpy Addition to Secondary from Hot Side of Boiler (Upflow) is over Twice the Enthalpy Addition Due to Cold Side (Downflow)

Conclusions and Future Work:

*Enthalpy bias in boiler may be better handled with 3D Model of Secondary

*Smoothing of Slug to Annular Flow Regimes in RELAP5 -3D Reduced the Amplitude of Limit Cycles first Predicted by Mod 3.2

*The Validation Study using MB-2 Data was Challenging but Manageable as a Course Project