# Use of RD-14/14M Data in CATHENA Validation

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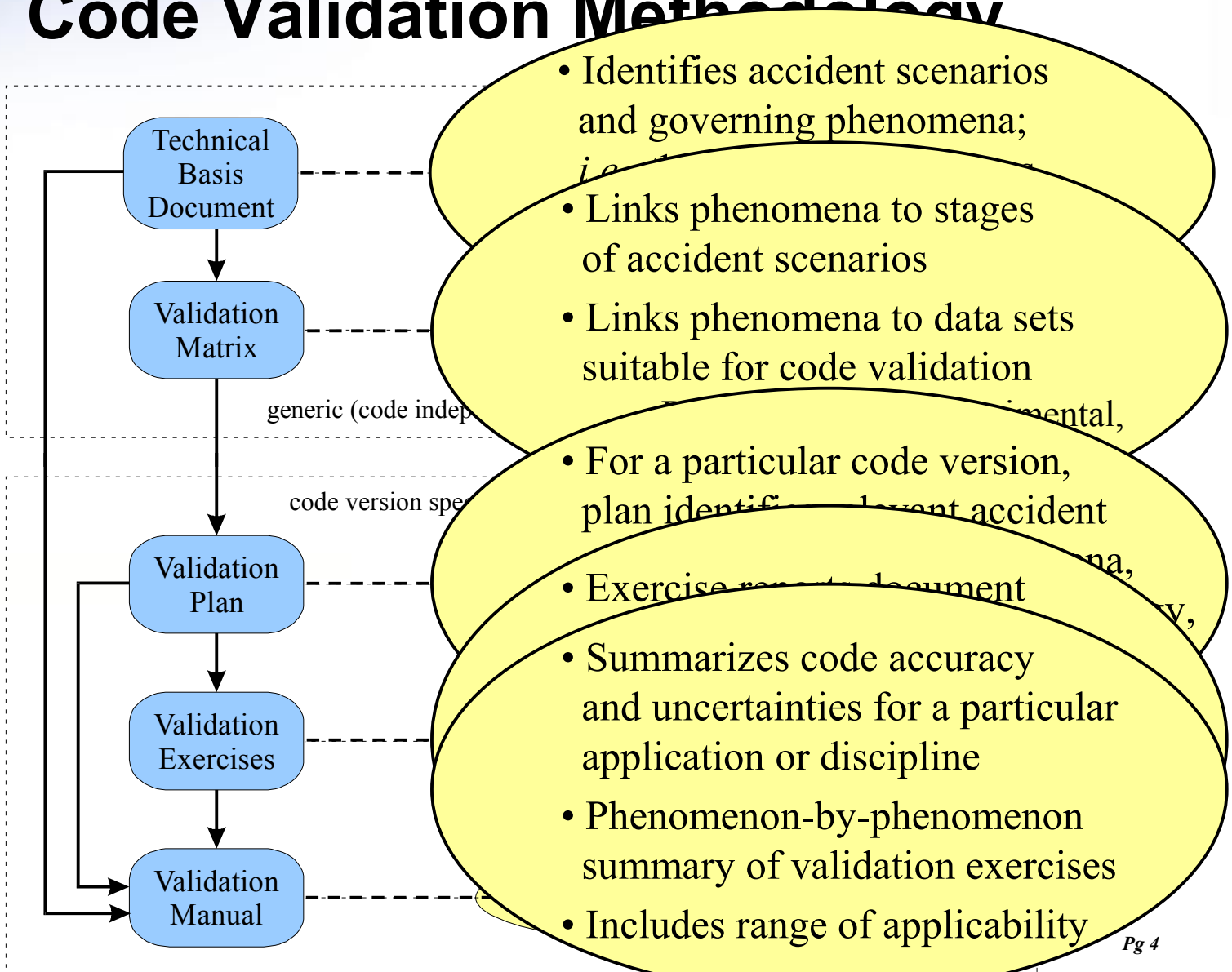
# Presentation Overview

- Very brief description of the CATHENA code
- Outline of the Industry-wide code validation methodology, and its application to CATHENA
- Summary of the validation of CATHENA MOD-3.5c, for existing CANDU system thermal hydraulics
  - Phenomenon by phenomenon basis
  - Sources of validation data
  - Use of RD-12/14/14M data in current validation
- RD-14/ACR data to confirm the validation of CATHENA MOD-3.5d, for ACR thermal hydraulics analyses

# CATHENA Code

- **Description:**
  - Canadian Algorithm for Thermal-hydraulic Network Analysis
  - One-dimensional, two-fluid system thermal hydraulics code
  - Developed by AECL primarily for analysis of postulated LOCA events in CANDU reactors
- **Applications:**
  - Large reactor design and analysis (CANDU 6, ACR, *etc.*)

# Code Validation Methodology



# CATHENA Validation Methodology – 1

- System Thermal Hydraulics Validation Matrix identifies 23 phenomena:
  - 21 phenomena are applicable to CATHENA
  - They represent the phenomena regarded as important in the sequence of events required to be analysed for ACR
- Each phenomenon is validated independently
  - Separate phenomenon validation plan, validation exercise reports, overview report
- Following two slides present table relating relevant phenomena to accident scenarios
  - Existing validation for current CANDU reactors
  - ACR-specific validation will be shown later

# Thermal Hydraulics Phenomena – 1
## (CANDU 6 specific)

| ID No. | Phenomenon | Large LOCA | LOCA/ LOECC | Small LOCA | LOF | LOR | Loss of Feed-water | Steam Line Break |
|---|---|---|---|---|---|---|---|---|
| TH1 | Break Discharge Characteristics and Critical Flow | ✓ | ✓ | ✓ | | | ✓ | ✓ |
| TH2 | Coolant Voiding | ✓ | ✓ | ✓ | × | × | | |
| TH3 | Phase Separation | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| TH4 | Level Swell and Void Holdup | × | × | ✓ | | | | ✓ |
| TH5 | HT Pump Characteristics (Single & 2-Phase) | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| TH6 | Thermal Conduction | ✓ | ✓ | ✓ | × | × | | |
| TH7 | Convective Heat Transfer | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| TH8 | Nucleate Boiling | | | ✓ | ✓ | | | |
| TH9 | CHF & Post Dryout Heat Transfer | × | × | ✓ | ✓ | ✓ | | |
| TH10 | Condensation Heat Transfer | ✓ | | ✓ | ✓ | | ✓ | ✓ |

✓ primary phenomena × secondary phenomena

continued on next slide ...

# Thermal Hydraulics Phenomena – 2
## (CANDU 6 specific)

| ID No. | Phenomenon | Large LOCA | LOCA/ LOECC | Small LOCA | LOF | LOR | Loss of Feed-water | Steam Line Break |
|---|---|---|---|---|---|---|---|---|
| TH11 | Radiative Heat Transfer | ✓ | ✓ | ✓ | ✓ | × | | |
| TH12 | Quench/Rewet Characteristics | ✓ | | ✓ | ✓ | ✓ | | |
| TH13 | Zirconium/Water Thermal-Chemical Reaction | ✓ | ✓ | × | | | | |
| TH14 | Reflux Condensation | | | × | ✓ | | × | × |
| TH15 | Counter-Current Flow | ✓ | | ✓ | ✓ | | ✓ | × |
| TH16 | Flow Oscillations | | | × | ✓ | ✓ | ✓ | ✓ |
| TH17 | Density Driven Flows (Natural Circulation) | × | × | ✓ | ✓ | | ✓ | ✓ |
| TH18 | Fuel Channel Deformation | ✓ | ✓ | × | | | | |
| TH20 | Water Hammer | | | × | | | × | |
| TH21 | Water Hammer (Steam Condensation Induced) | × | | | | | | × |
| TH23 | Non-Condensable Gas Effects | × | × | × | × | | | |

# Sources of Validation Data

- Analytical solutions to idealized problems
- Separate effect experiments
  - Isolate behavior of a single phenomenon
  - May be of Canadian or international origin
- Component tests
  - Investigate one or more phenomena in a reactor-specific geometry or assembly
- Integrated tests
  - Investigate interacting phenomena in inter-connected components relevant to reactor geometry
  - Includes RD-12, RD-14, RD-14M and in-reactor tests

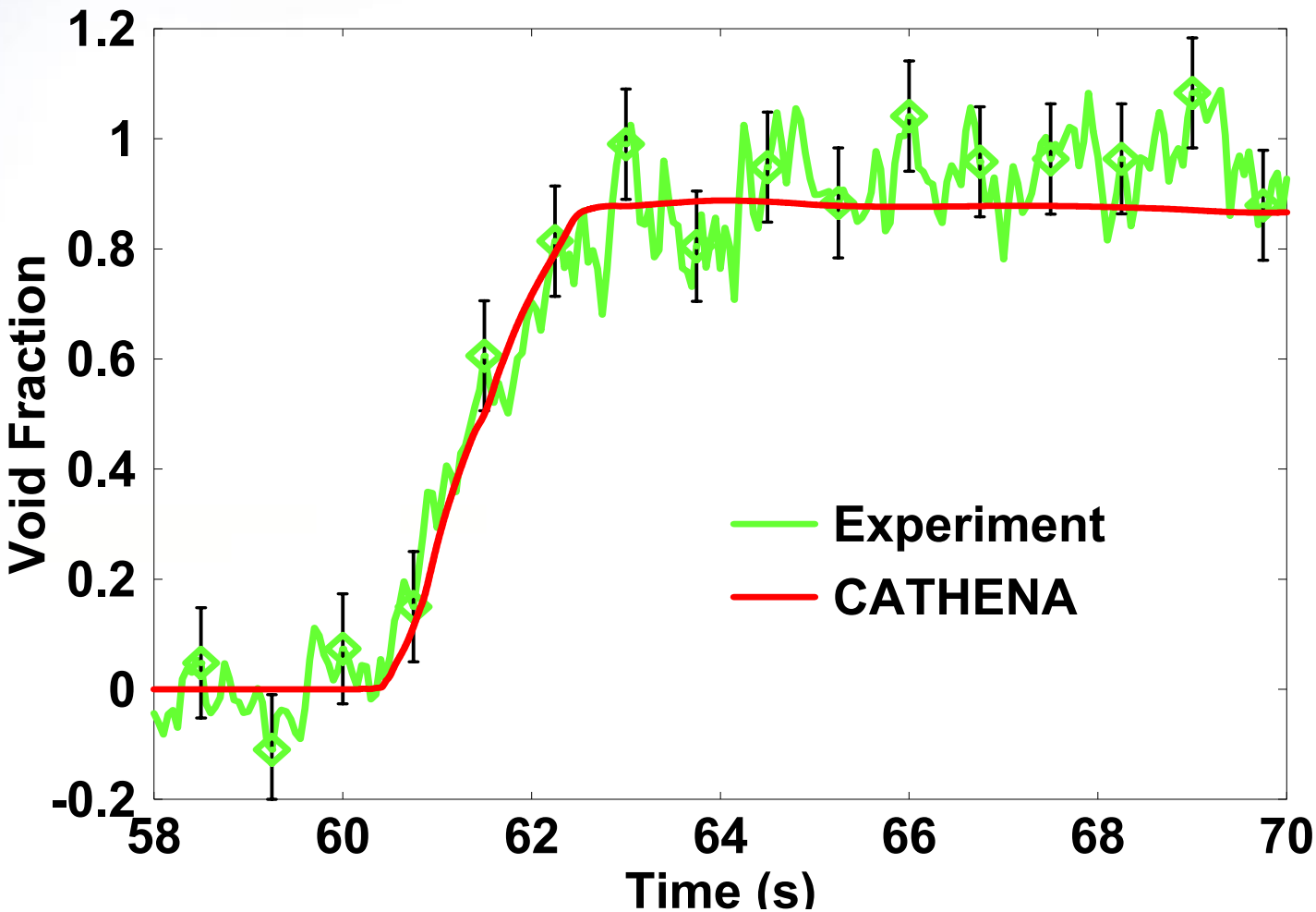
# RD-12/14/14M Data Usage

| ID No. | Phenomenon | Number of Tests Used | | |
|---|---|---|---|---|
| | | RD-12 | RD-14 | RD-14M |
| TH1 | Break Discharge & Critical Flow | 3 | 5 | 3 |
| TH2 | Coolant Voiding | | 5 | 13 |
| TH3 | Phase Separation | | 4 | |
| TH4 | Level Swell and Void Holdup | 7 | | |
| TH5 | HT Pump Characteristics | | 1 | |
| TH7 | Convective Heat Transfer | | 2 | 2 |
| TH8 | Nucleate Boiling | | | 3 |
| TH9 | CHF & Post Dryout Heat Transfer | | | 2 |
| TH10 | Condensation Heat Transfer | | 4 | 4 |
| TH12 | Quench/Rewet Characteristics | 1 | 3 | |
| TH16 | Flow Oscillations | | 2 | 4 |
| TH17 | Natural Circulation | | 3 | 6 |
| Totals | | 9 | 12 | 31 |

**Note:** the "totals" do not equal the sum of the column values because some tests are used for the validation of more than one phenomenon.

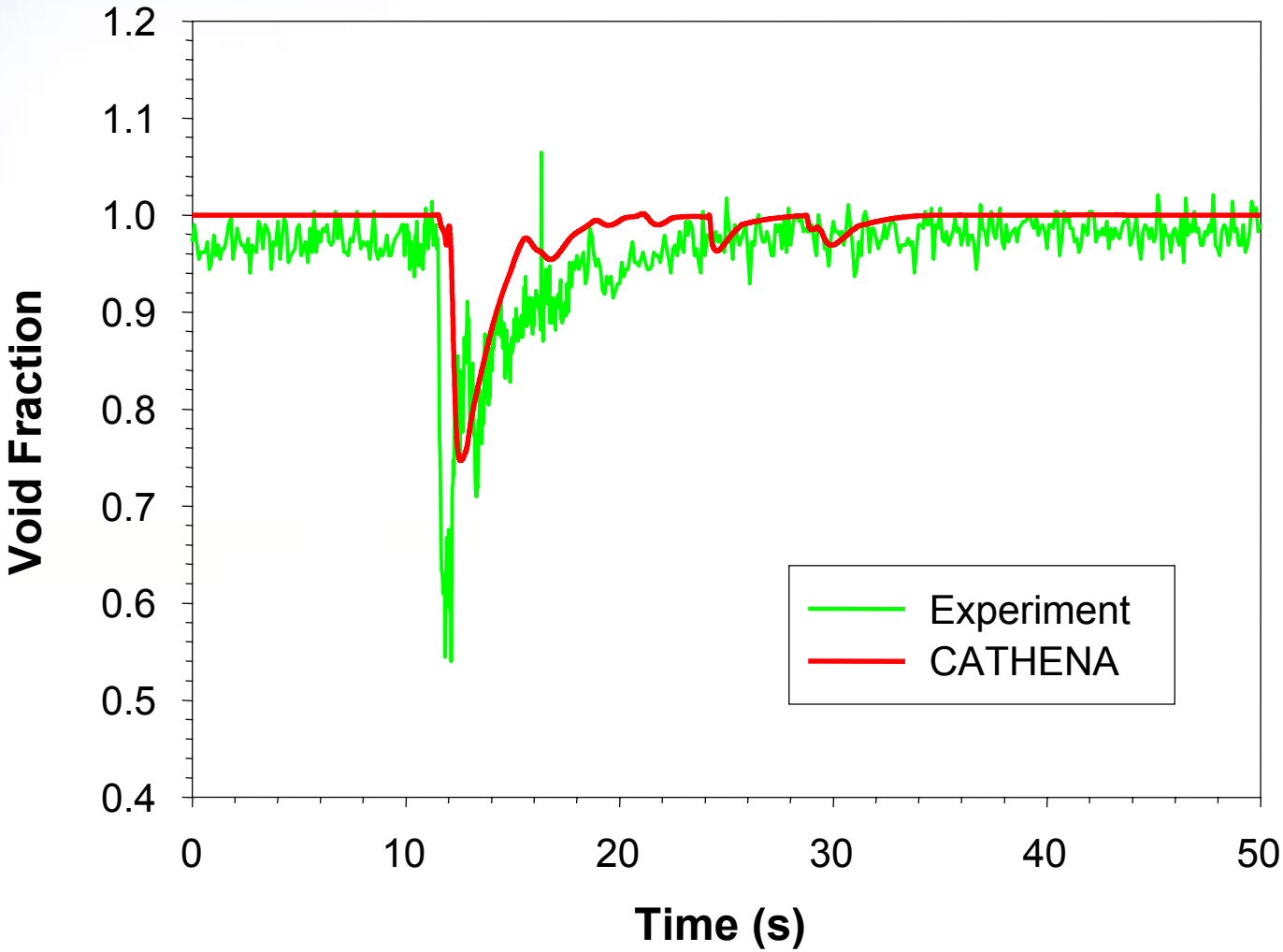
# TH2: Coolant Voiding

## RD-14M Test B0105, 25-mm Inlet Header Break



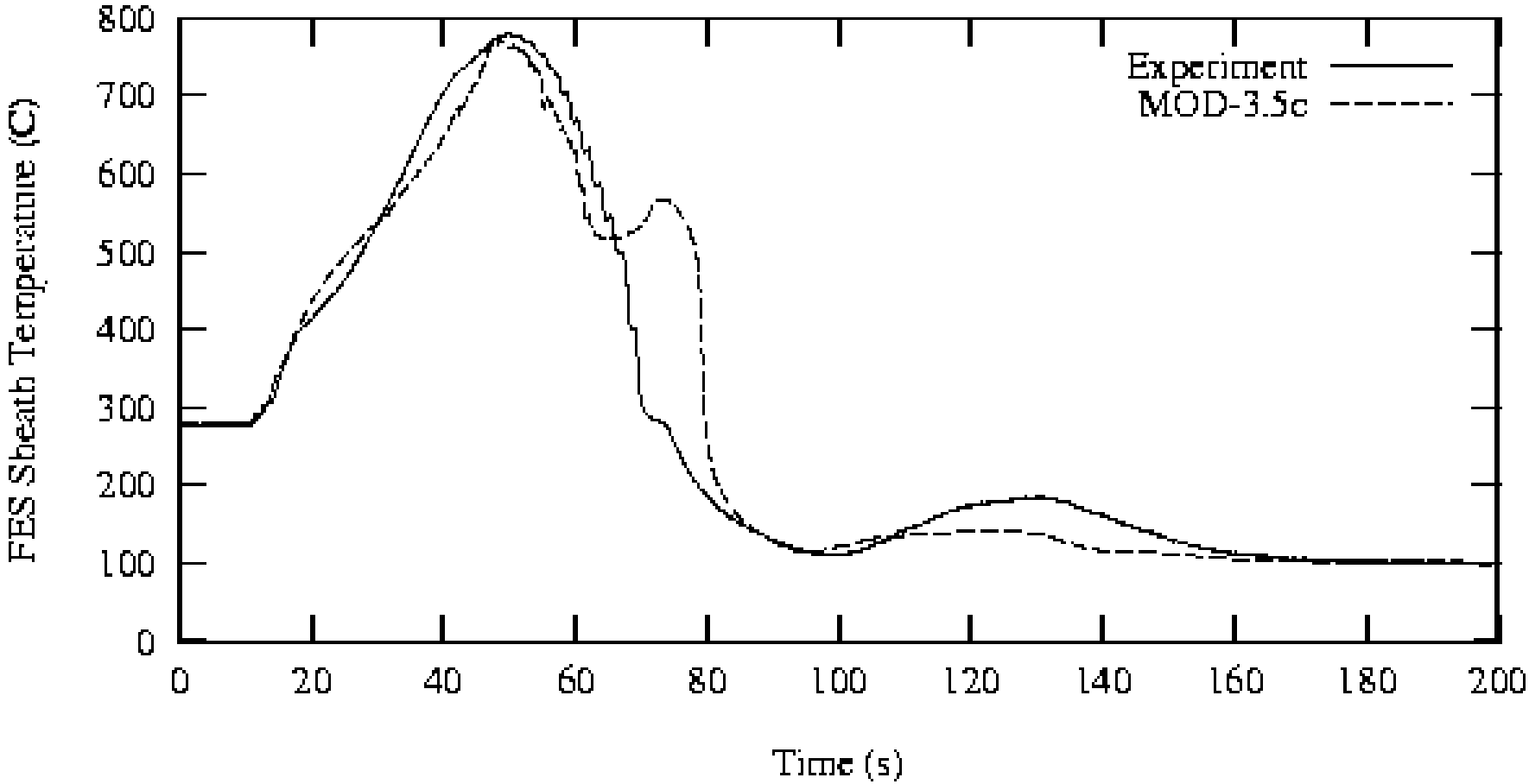
# TH4: Level Swell and Void Holdup

## RD-12 SG Blowdown Test B8506: Void in Steam Line



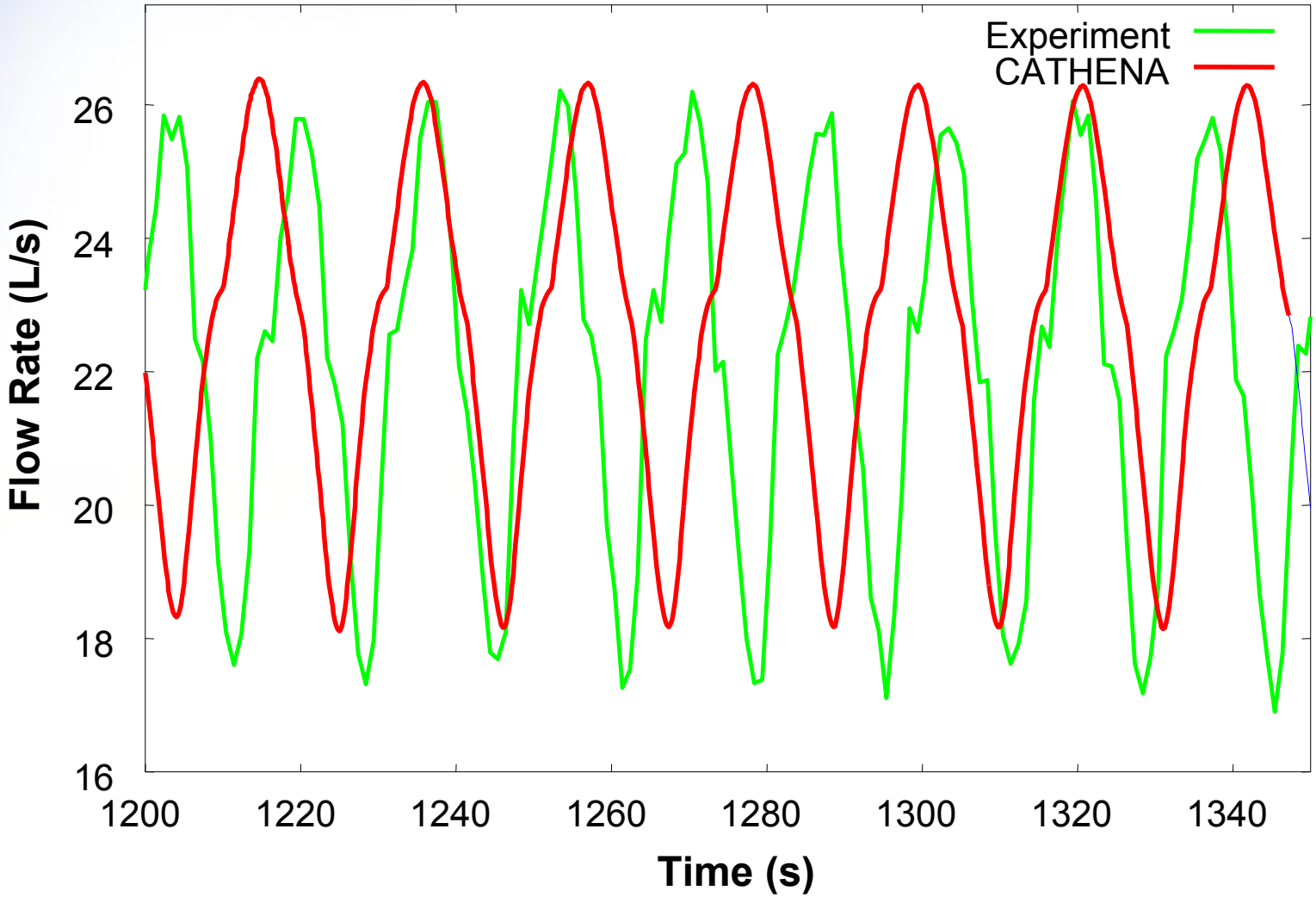
# TH12: Quench/Rewet Characteristics

## RD-14M Large Break Blowdown Test B0002, TS13 Inlet



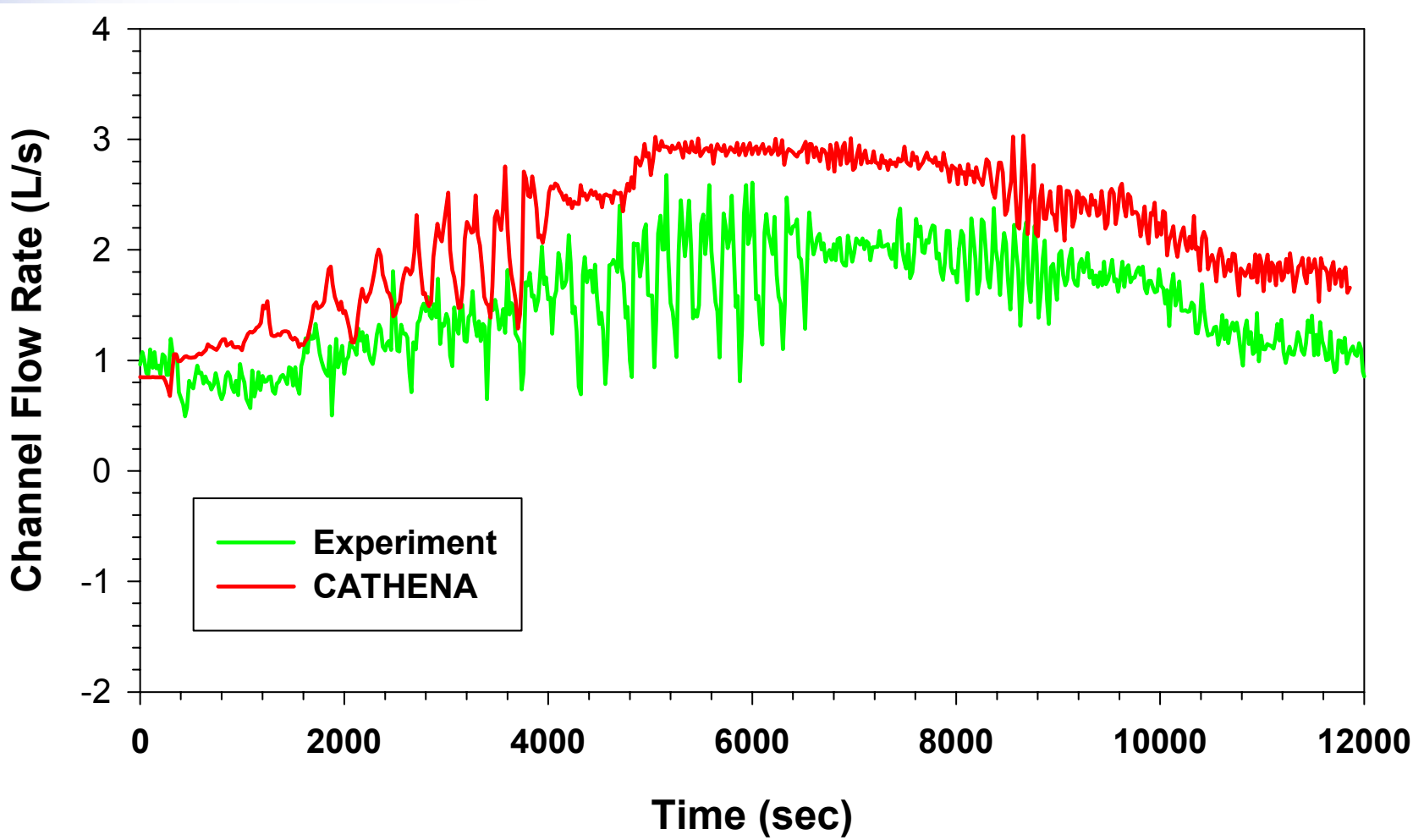
# TH16: Flow Oscillations

## RD-14 Flow Stability Test L8708: TS1 Inlet



# TH17: Density Driven Flows (Natural Circulation)

## RD-14 Natural Circulation Test T8619: TS1 Inlet



# Validation Methodology for ACR

- ACR-specific Technical Basis Document has been issued:
  - Small changes to list of accident scenarios
  - No change to the governing thermal hydraulic phenomena
- ACR-specific Validation Matrices will also be produced:
  - New data sets will be identified, where required
  - For some phenomena, additional experiments will be performed
- ACR safety and licensing thermal hydraulic analyses will be performed with CATHENA MOD-3.5d:
  - Existing validation of MOD-3.5c is applicable
  - Validation will be extended to ACR conditions

# ACR-Specific Validation With RD-14/ACR Data

- Additional validation, against RD-14/ACR data at ACR conditions, is expected to confirm the applicability of CATHENA to ACR:
  - 9 small break blowdown tests performed, to be used for validation of break discharge [TH1] and coolant voiding [TH2]
  - 4 steady-state heat transfer tests proposed for validation of liquid convection [TH7] and nucleate boiling [TH8] heat transfer
  - 1 or 2 very small break blowdown tests suggested for validation of nucleate boiling [TH8] and condensation [TH10]
  - RD-14/ACR tests of the improved ECC design will also be simulated

# Summary

- CATHENA MOD-3.5c has been well-validated for CANDU reactor system thermal hydraulics analyses
  - Have demonstrated that the validation relies heavily on RD-12, RD-14 and RD-14M data
  - Examples shown
- Validation will be extended to include ACR conditions
  - Current validation is applicable to ACR
- RD-14, RD-14M and RD-14/ACR provide high-quality data that has proven crucial for thermal hydraulic code validation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