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

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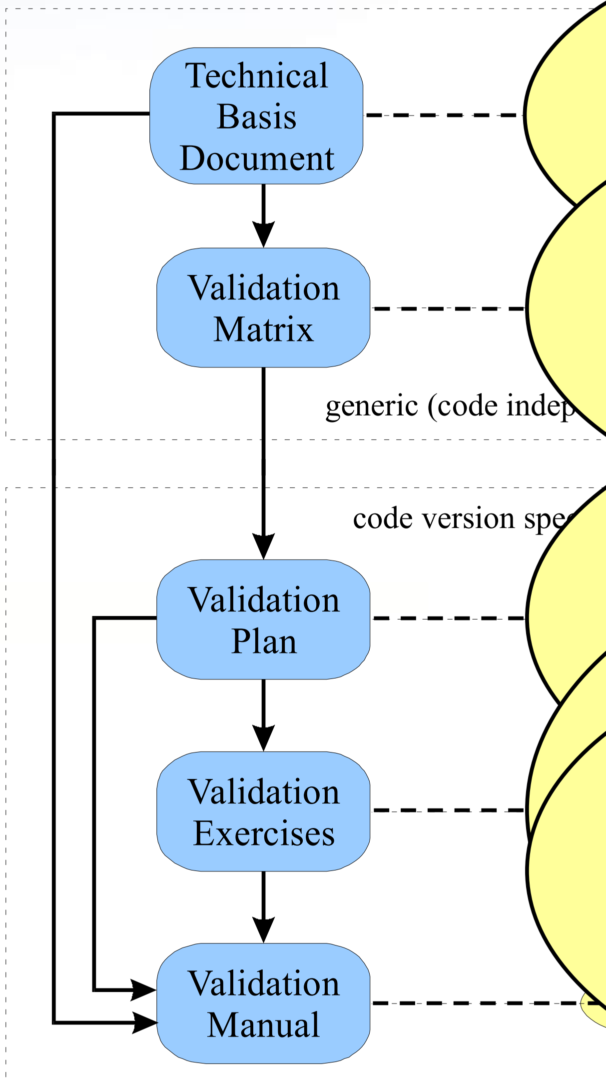
Presentation Overview

- 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



- Identifies accident scenarios and governing phenomena;

- Links phenomena to stages of accident scenarios
- Links phenomena to data sets suitable for code validation

- For a particular code version,

- Summarizes code accuracy and uncertainties for a particular application or discipline
- Phenomenon-by-phenomenon summary of validation exercises
- Includes range of applicability

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

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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

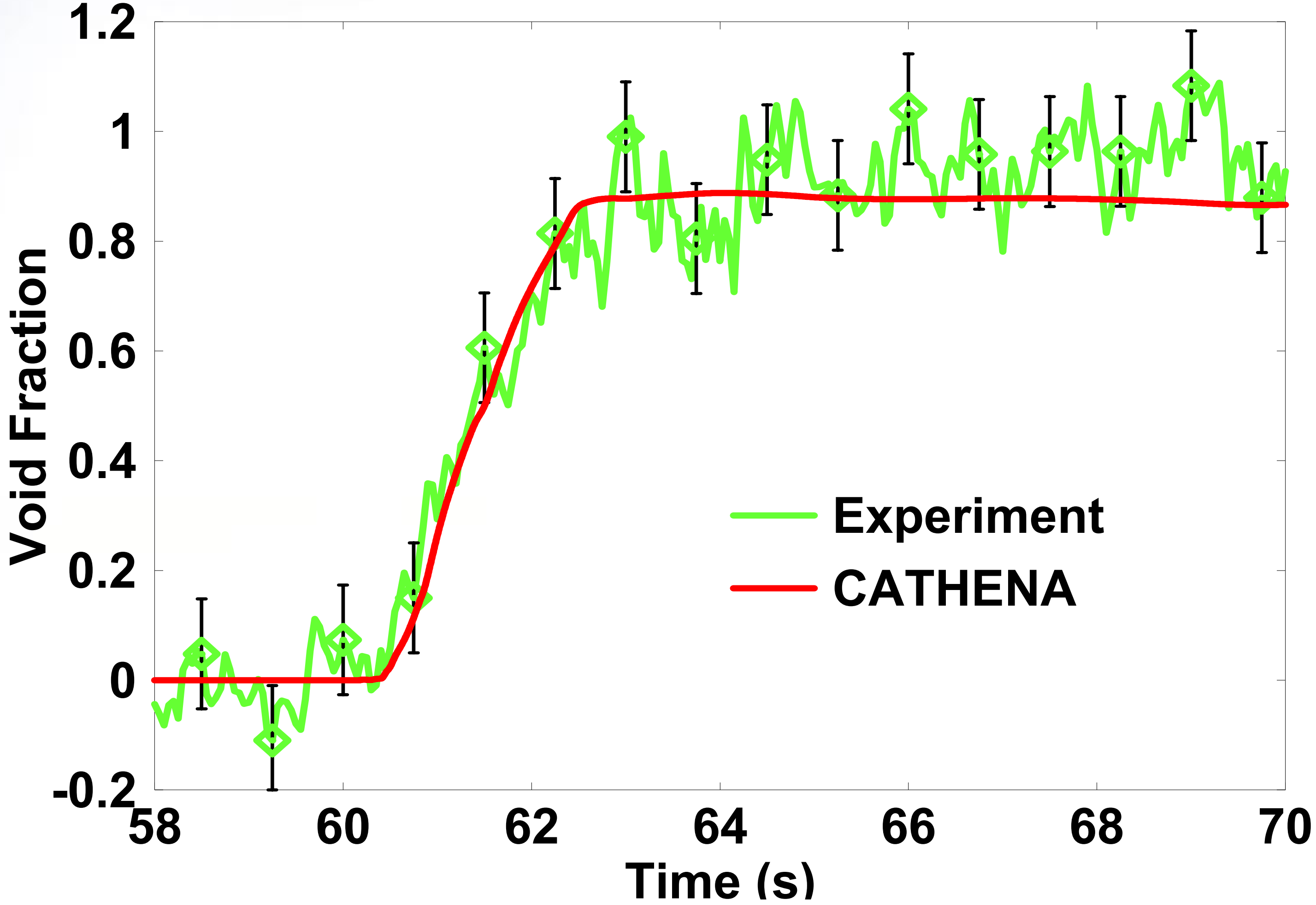
RD-12/14/14M Data Usage

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.

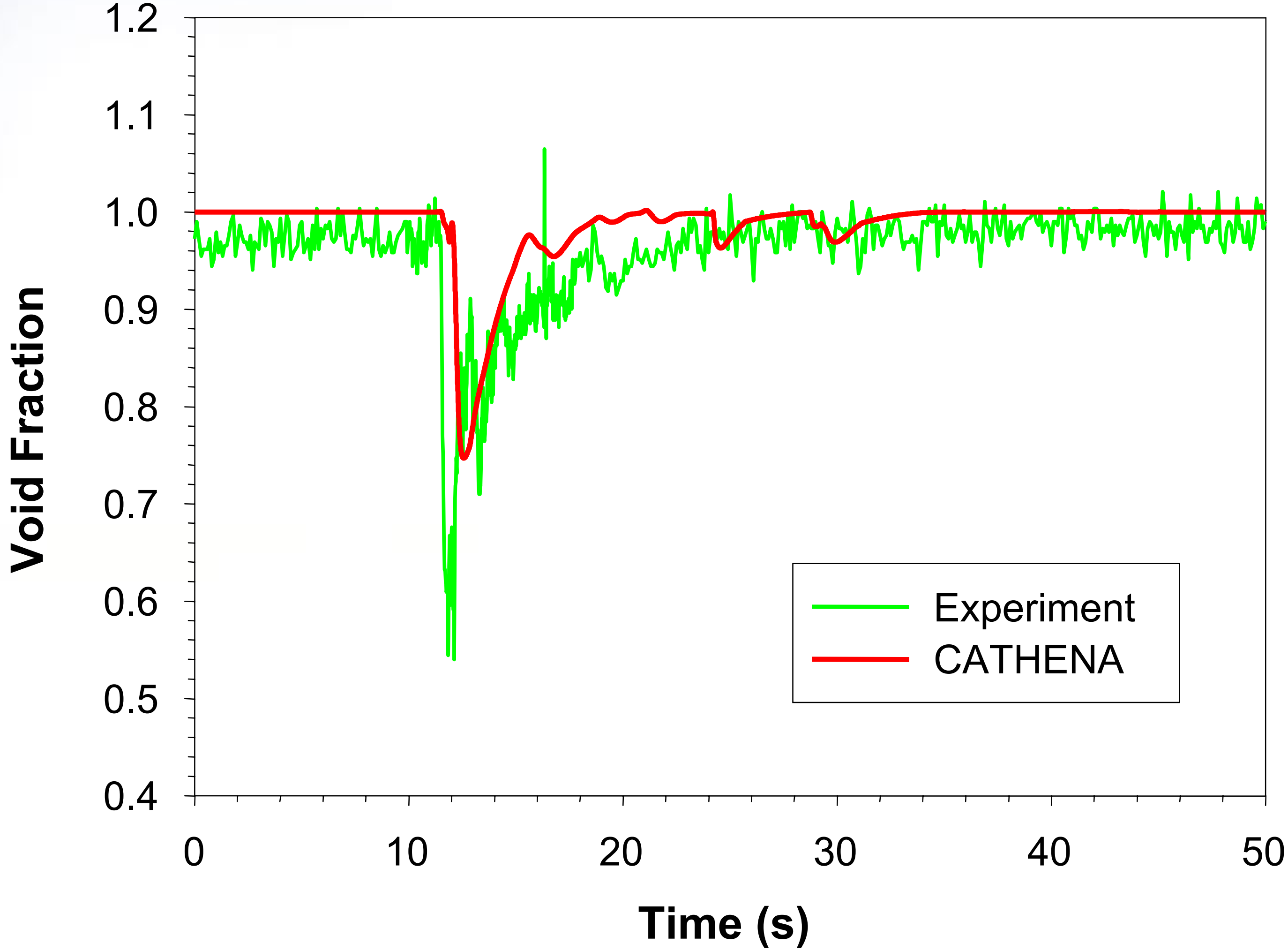
TH2: Coolant Voiding

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

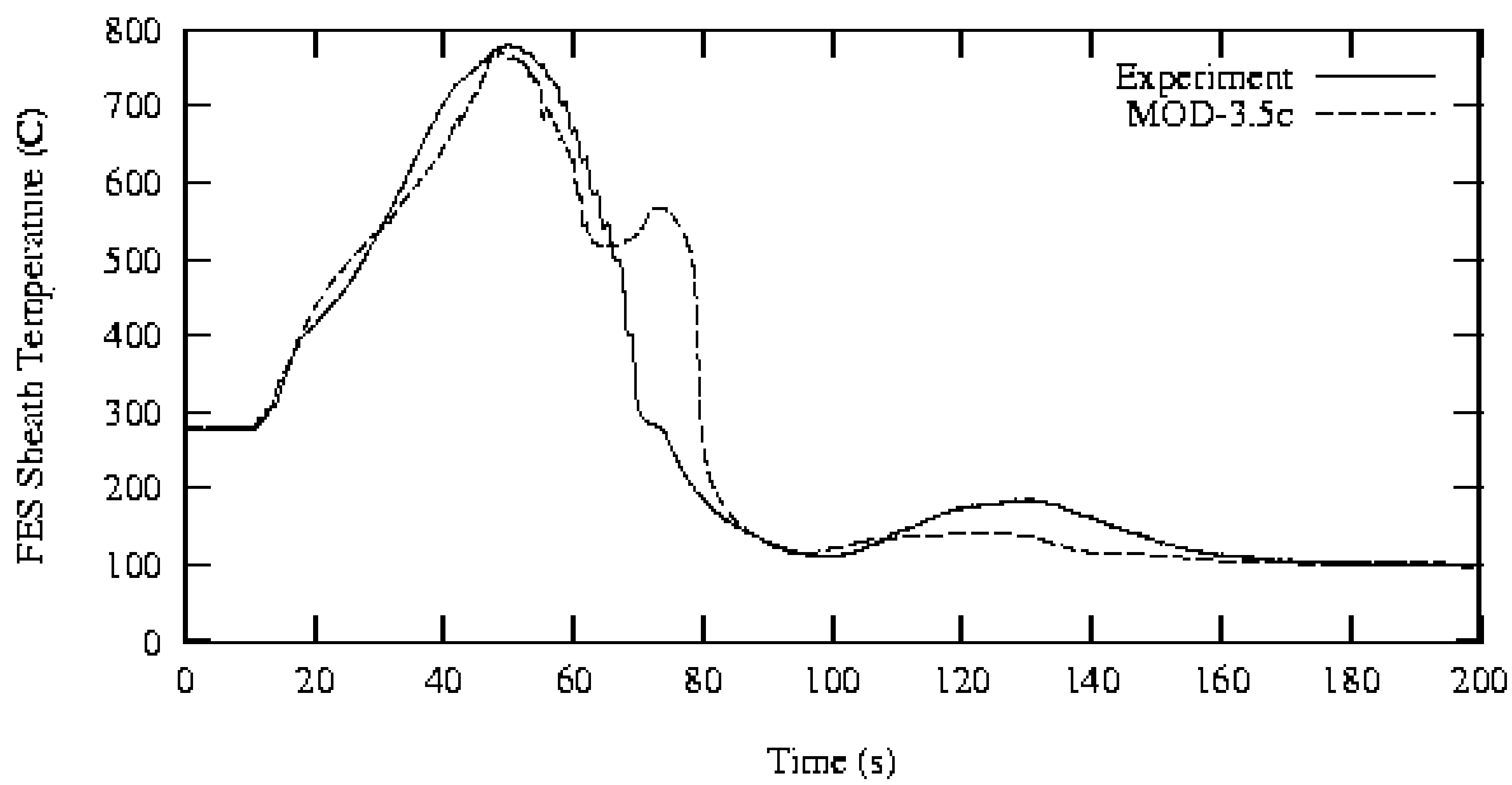


TH4: Level Swell and Void Holdup

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

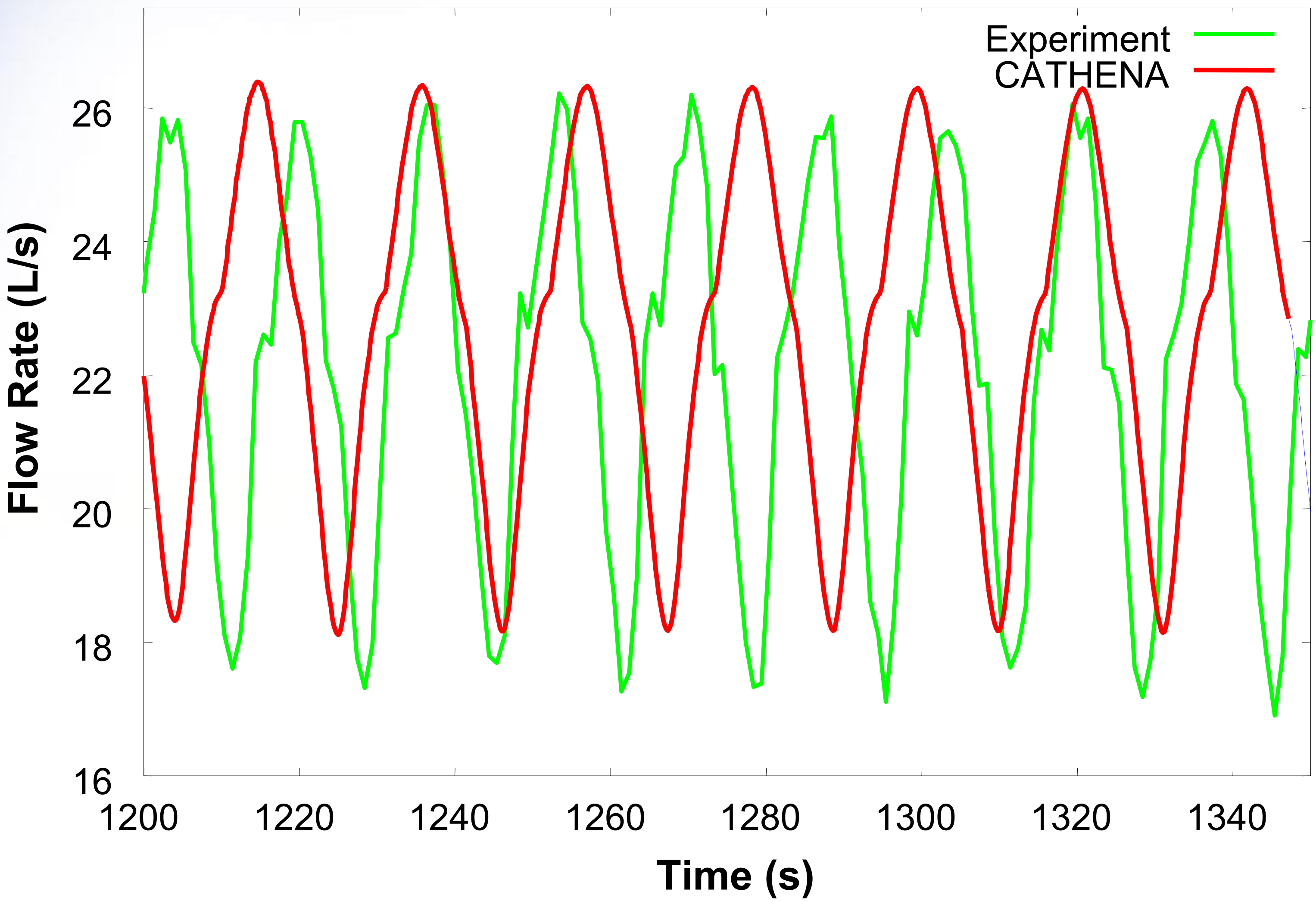


TH12: Quench/Rewet Characteristics
RD-14M Large Break Blowdown Test B0002, TS13 Inlet



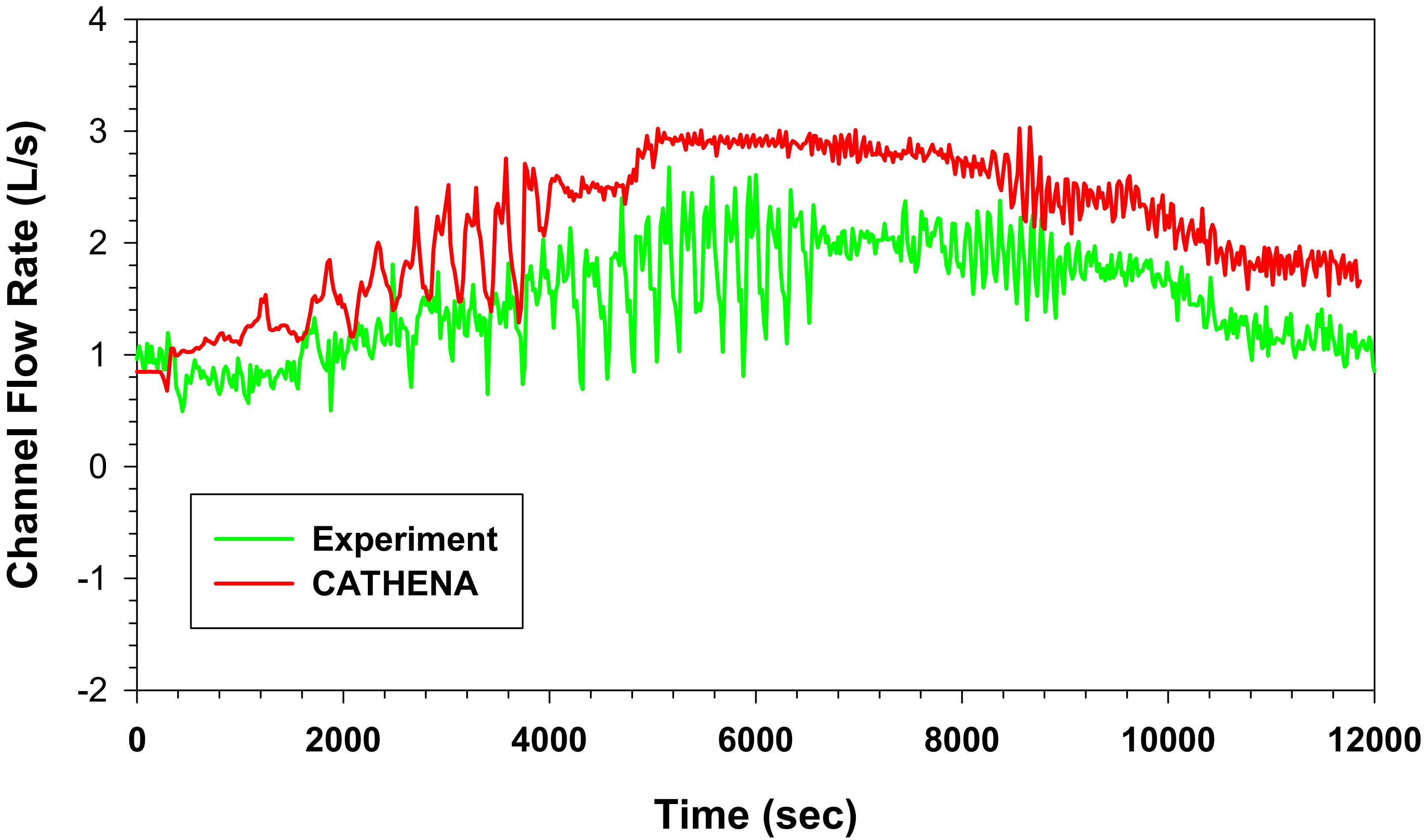
TH16: Flow Oscillations

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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