

Qualification of System Codes for New Builts - Code Requirements and Model Improvement

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Outline

- Background
- Overview of AC²
- General Validation Strategy of AC²
- Specific Validation for Passive Systems
- Conclusions

Background

Background

- Nuclear new builds in Europe in the medium term will be focused mainly on Gen III/III+ LWR designs including LWR SMRs.
- In the long term, Gen IV reactor concepts might play a role.
- These new designs pose specific challenges for the development but also for the verification and validation (V&V) of system thermal-hydraulics codes (STH), which often are legacy codes.
- STH will be the working horse to support the safety demonstration of a new build for the foreseeable future.
- For using STH in licensing, these codes need to be properly qualified. Relevant good practice for V&V is given e.g. in IAEA SSG-2 and several regulatory guides. Expectations on a robust V&V of STH for new challenges from new builds like passive safety systems with small driving forces, innovative components or new materials require to enhance internal procedures and processes, including use of continuous integration techniques.
- Extension of validation matrices with specific validation for passive safety systems and innovative safety features

Overview of AC²

Motivation for the Development of AC²

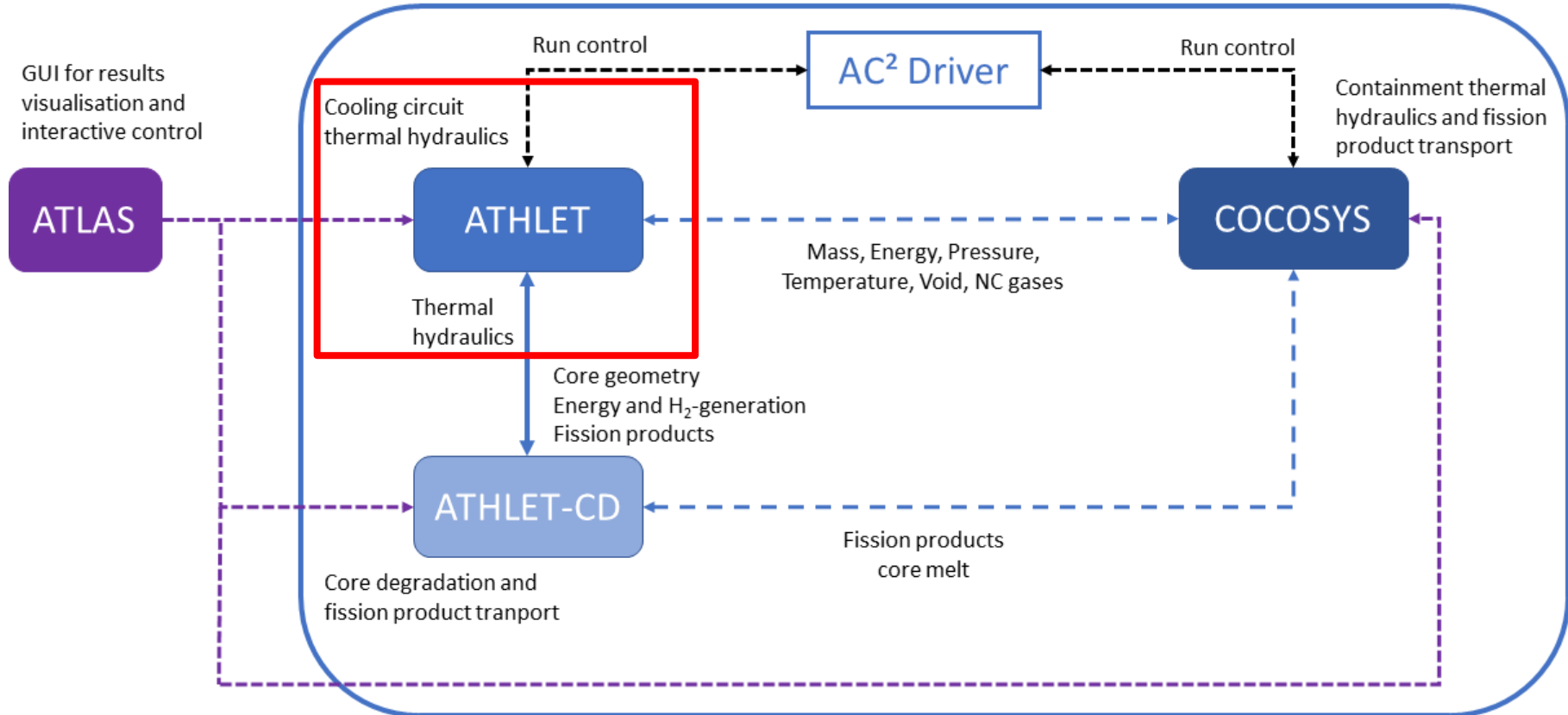
New reactor concepts (Gen III/III+, SMRs, ADS, ...) impose new **challenges**:

- **Passive safety** systems, including large water pools
- **Innovative** components (e.g. compact heat exchanger, heat pipes)
- New **working fluids** (e.g. LBE, sodium, helium,)
- Require partially coupled (multi-physics) simulations of phenomena in the core, cooling circuit, containment and fuel pool

AC² takes up these challenge by:

- Coupling ATHLET/ATHLET-CD und COCOSYS for the **integral co-simulation** of flow phenomena in cooling circuit and containment
- Specific models for **passive safety systems** and innovative components
- Extension to new **working fluids**, homogenization of material values
- **Integral validation** of the overall system
- Coupling interfaces for **multi-physics/multiscale analyses** (CFD, CSM, subchannel codes, 3D neutronics)

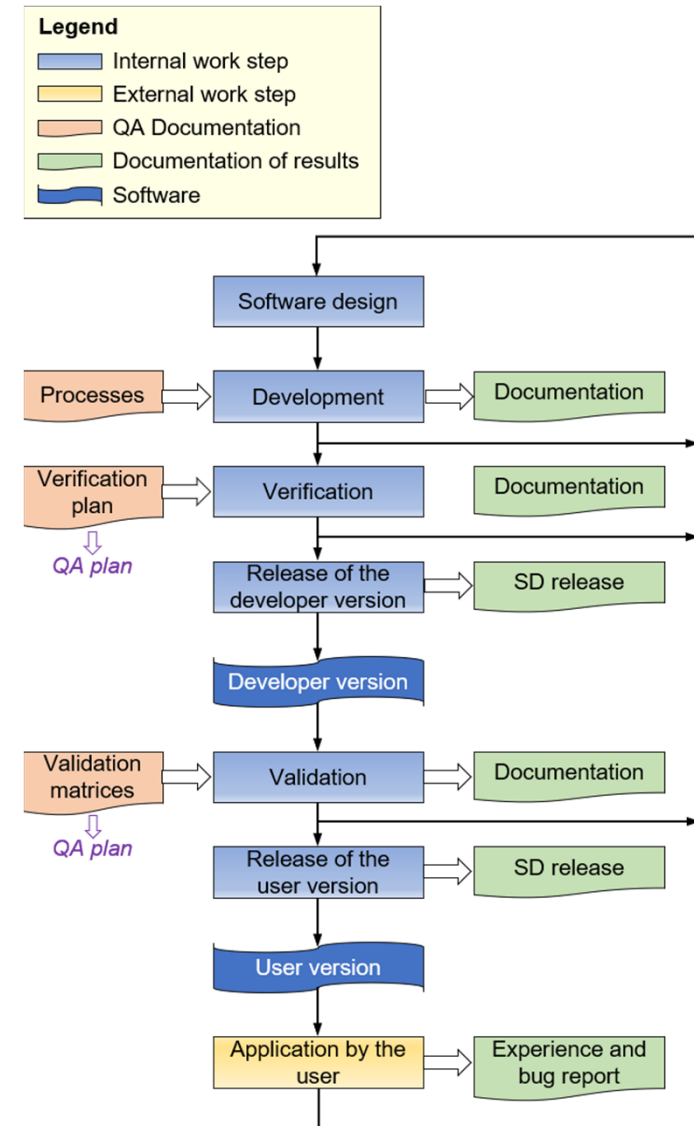
AC² 2019 – Architecture and Main Codes



General Validation Strategy of AC²

Overview of validation activities (I)

- QM Guidelines for computer programs
- Separation of *Development and Verification* and *Validation*
 - Verification: check, whether models are implemented correctly
 - Validation: check, whether physical phenomena are described by the correct models
 - Phenomena orientated validation matrix
 - Single effect tests (SET): selected effects, clearly defined initial and boundary conditions, high instrumentation density and quality
 - Integral tests: interaction of different effects, normally scaled test facilities, common special instrumentation



Overview of validation activities (II)

– AC²/ATHLET –

- **PWR**: 105 relevant
Experiments / Transients
→ 75 % calculated
- **BWR**: 18 relevant
Experiments / Transients
→ 100 % calculated
- **WWER**: 37 relevant
Experiments / Transients
→ 98 % calculated
- Gen. III/III+, IV, SMR
extensive number of
new phenomena
large new test matrices
→ big effort
- Work performed also with the
help of external partners

Facility or Plant	Scale	Pressurized Water Reactors					Boiling Water Reactors	
		Large breaks	Small and medium breaks	Transients	Transients with loss of RHRS	AM	LOCAs	Transients
UPTF/TRAM	1:1	6 / 2	2 / 2			3 / 1		
CCTF	1:25	4 / 4						
LOFT	1:50	2 / 2	4 / 3	1 / 0				
LSTF	1:50		2 / 1			2 / 2		
BETHSY	1:100		7 / 7		3 / 1	5 / 4		
PKL	1:145	2 / 2	13 / 8	7 / 2	3 / 3	7 / 4		
LOBI	1:712	2 / 2	8 / 6	4 / 3		2 / 2		
GERDA*	1:1686		1 / 1					
ROSA-III	1:424						5 / 5	1 / 1
FIST	1:642						2 / 2	1 / 1
German Konvoi				3 / 3				
KBR				4 / 4				
KKU				3 / 3				
KKP-2				5 / 5				
KKP-1								3 / 3
KRB								3 / 3
KKK								3 / 3
TOTAL		16 / 12	37 / 28	27 / 20	6 / 4	19 / 13	7 / 7	11 / 11

*) PWR with once-through steam generators

Facility	Scale	Large breaks	Small and medium breaks	Transients	Transients with loss of RHRS	AM
PMK	1:2070		6 / 6		2 / 2	
ISB	1:3000		6 / 6			
PACTEL	1:305		9 / 5	2 / 2		2 / 2
PSB WWER	1:300	1 / 1	3 / 3			
Greifswald (U4)	1:1			2 / 2		
Dukovany	1:1			2 / 2		
Bohunice	1:1			1 / 1		
Kosloduj (U6)	1:1			1 / 1		
TOTAL		1 / 1	24 / 20	8 / 8	2 / 2	2 / 2

Specific Validation of ATHLET for Passive Systems

Extension of Validation Matrices for Passive Systems

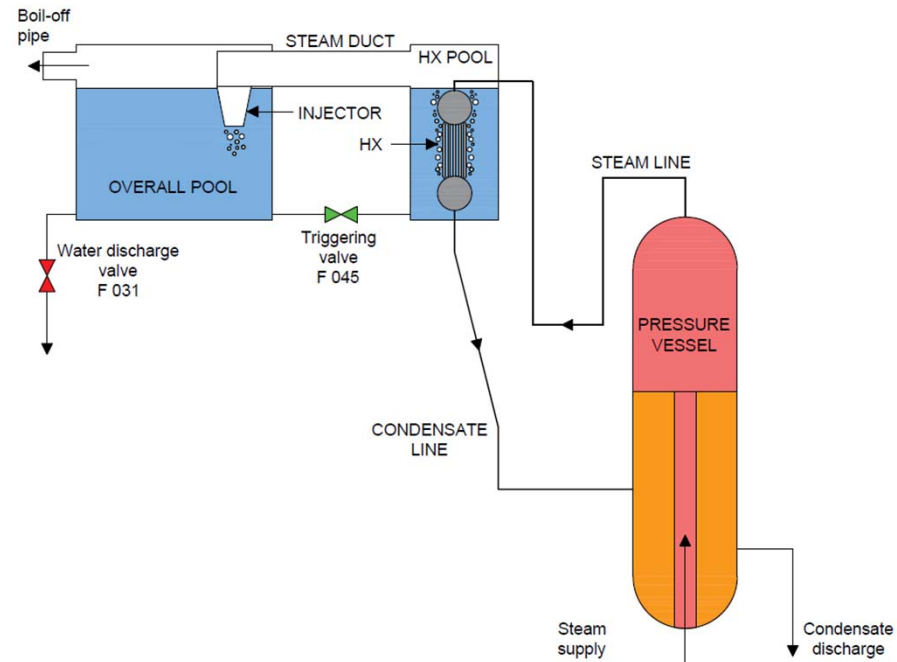
The extension of validation matrices is ongoing

- Identification of relevant phenomena of passive systems especially those less relevant for or not applicable in active systems (for safety demonstration)
- Identification of experiments investigating passive systems and considering the phenomena relevant for passive systems, e.g.:
 - Emergency condenser of INKA
 - Emergency condenser Jülich
 - UPTF TRAM A6
 - Selected experiments of the ATLAS test series considering passives systems
 - PKL SACO (part of EC PASTELS project)
 - Selected experiments identified in EC ELSMOR project
 - PERSEO **Test No. 7** (OECD Benchmark) and No. 9

Simulation of PERSEO Test No. 7

Scope of the experiment

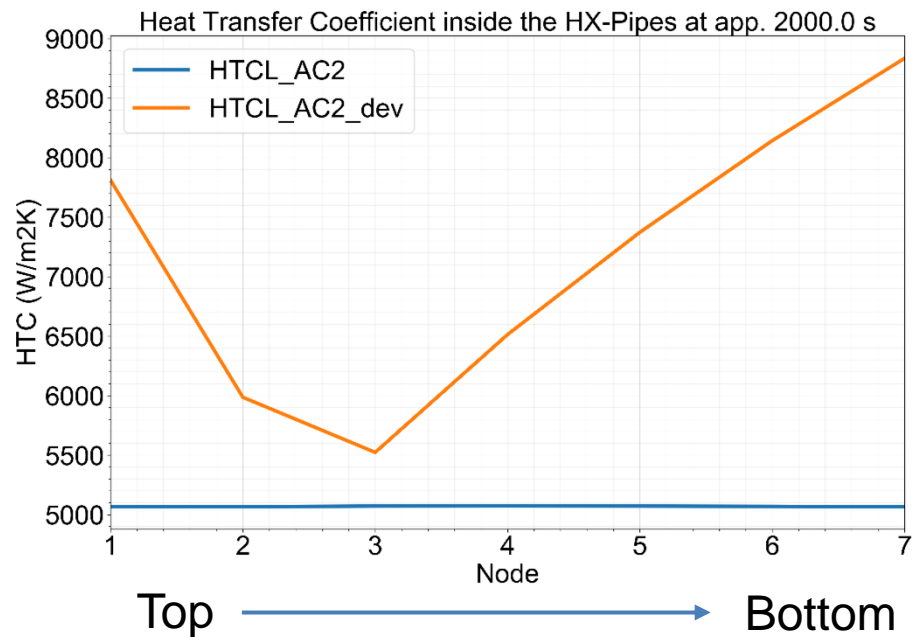
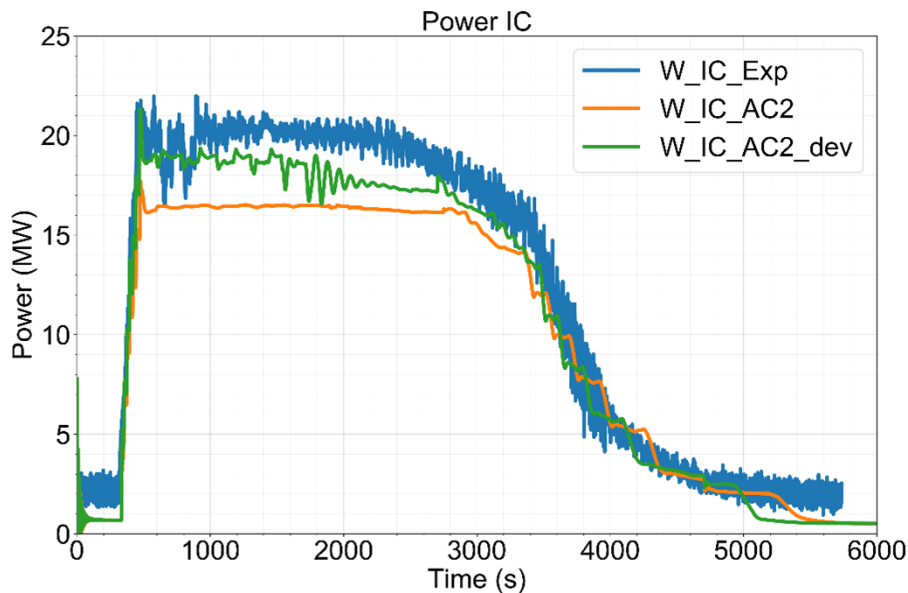
- Test 7 is a full pressure test (7 MPa) and investigates the system stability and the system operation (long term cooling capability)
- The test consists of two parts:
 - Part 1: to verify the behavior of the system with two different water levels
 - Part 2: to verify the long term cooling capability of the system



OECD/NEA PERSEO benchmark results report

Simulation of PERSEO Test No. 7 – Results –

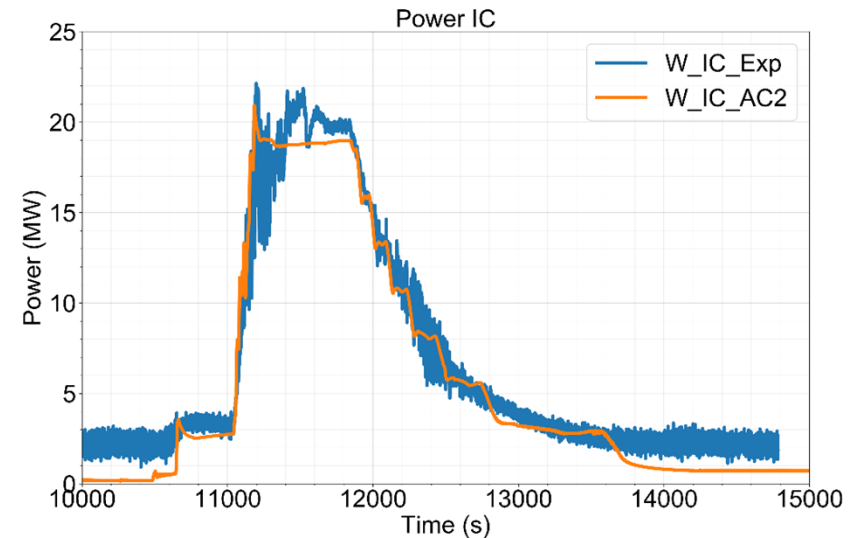
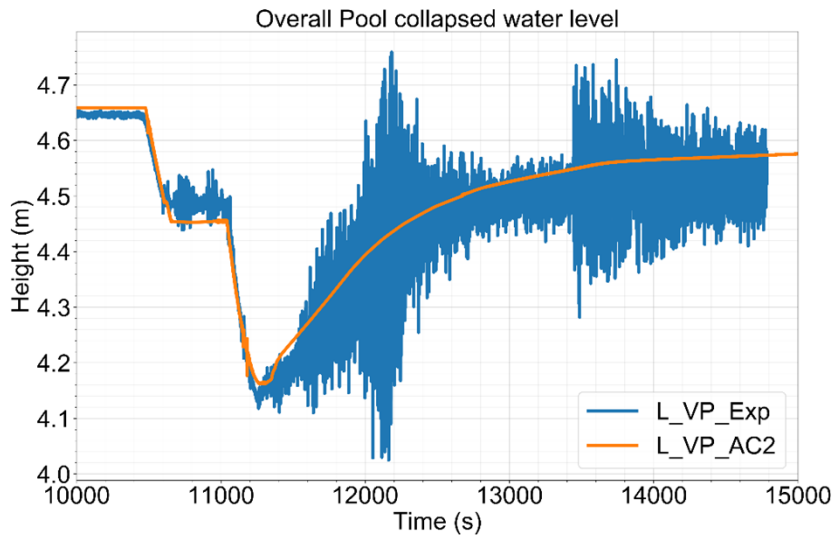
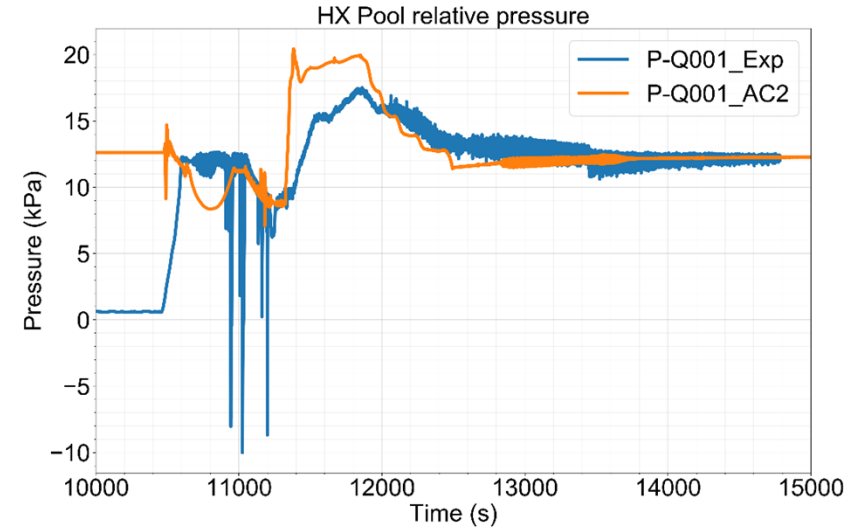
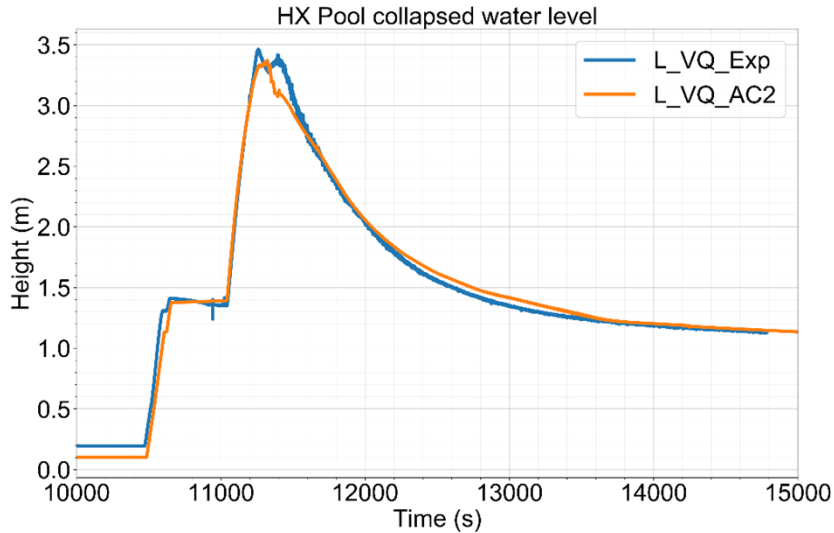
Application of ATHLET including additional correlations for condensation heat transfer within vertical tubes



- Underestimation of transferred power of approx. 5 – 10 %
 - Differences to ATHLET standard version: up to 20 %
 - Correlations will be included in future ATHLET versions

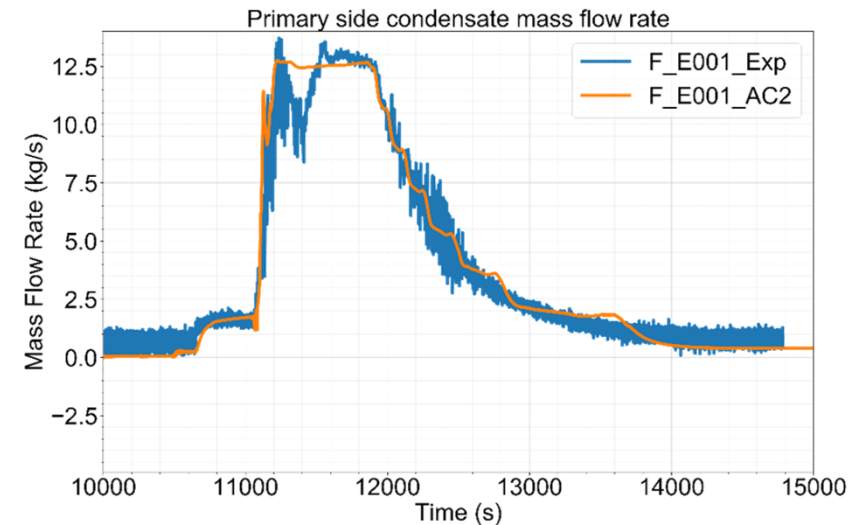
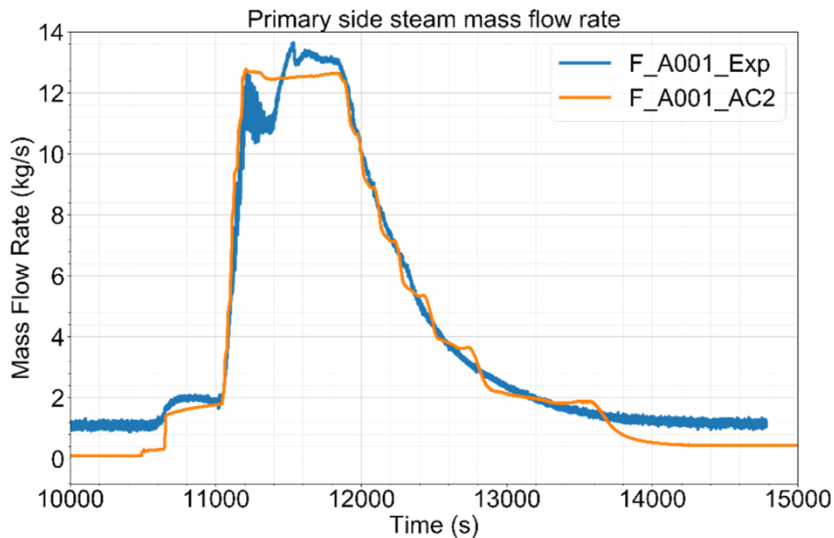
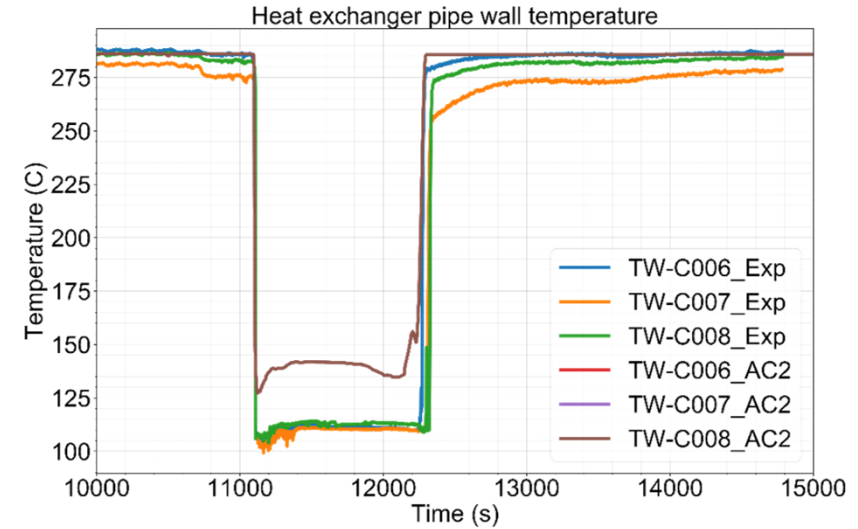
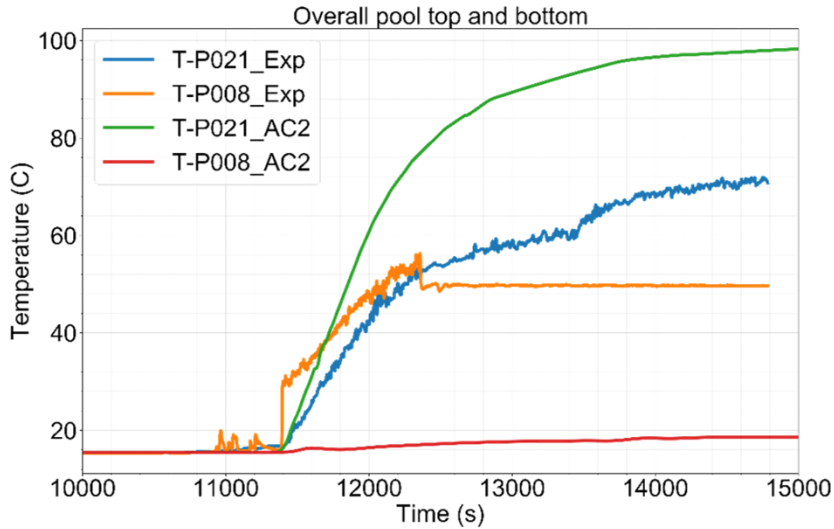
Simulation of PERSEO Test No. 7

– Results Part 1 (I) –



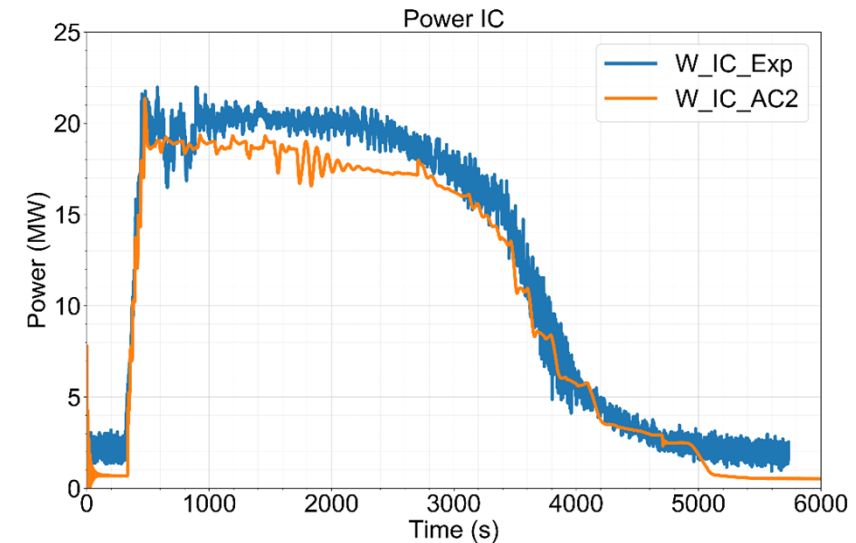
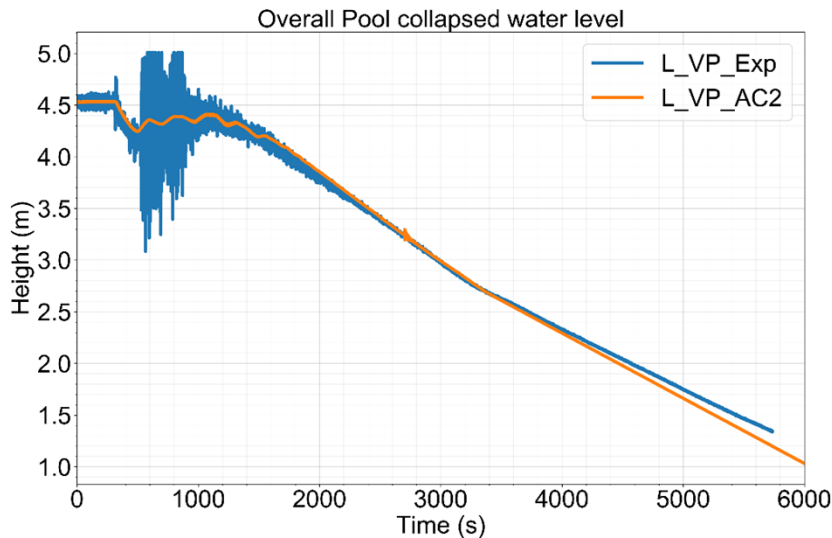
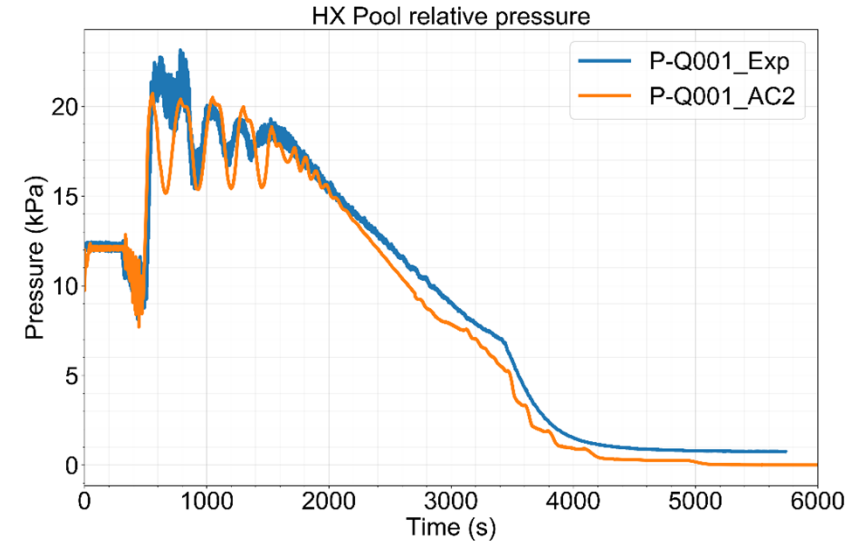
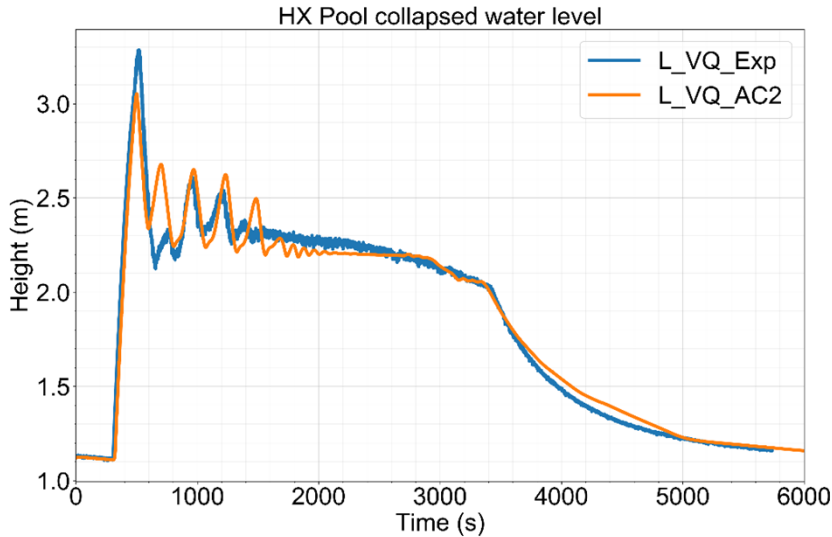
Simulation of PERSEO Test No. 7

– Results Part 1 (II) –



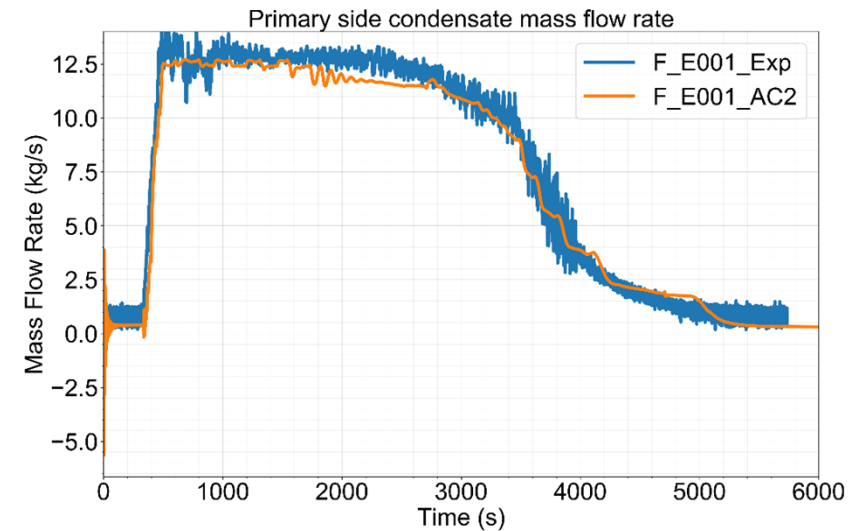
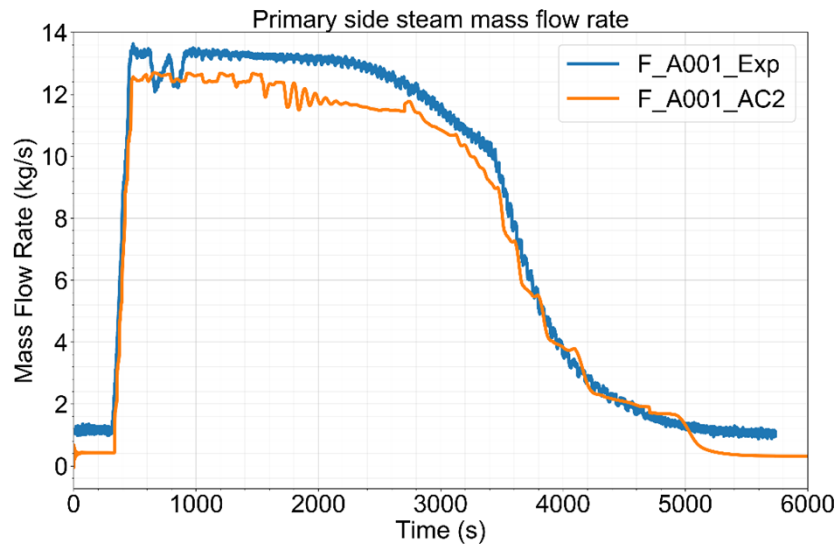
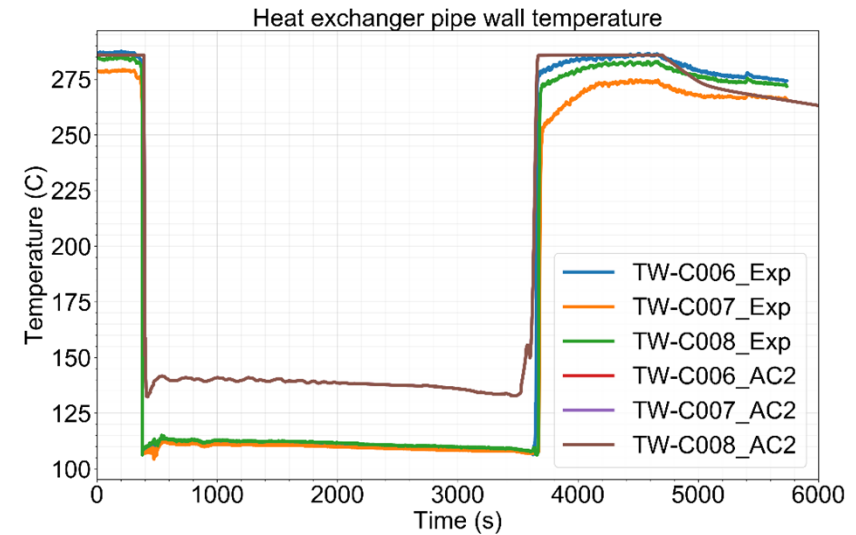
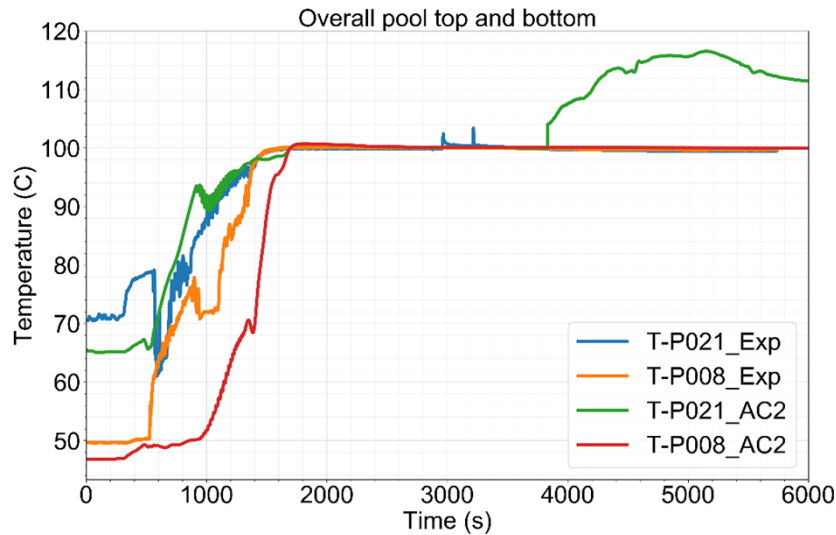
Simulation of PERSEO Test No. 7

– Results Part 2 (I) –



Simulation of PERSEO Test No. 7

– Results Part 2 (II) –



Conclusions and Outlook (I)

- The results of the validation simulations show that the AC² module ATHLET can be successfully applied for thermal-hydraulics of LWR Gen II, III including **passive systems** by application on selected experiments and plants
- The V&V of the AC² modules ATHLET and ATHLET-CD will be continued to assure the capability and predictability of the modules. Intensive validation by
 - Systematically increasing verification and validation cases
 - Increased use of a CI server as basis for evaluation and expert judgement
 - (Re-)Calculation of Single Effect Tests
- Extended validation of AC² with coupled ATHLET(-CD)/COCOSYS scenarios
- Participation in international activities, especially OECD/NEA activities and EC sponsored projects
 - **For code usage and experimental data exchange**

Acknowledgment

The development and validation as well as application and assessment of AC² are sponsored by the German Federal Ministry for Economic Affairs and Energy (BMWi).

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Thank you very much for your attention!