Program and Test Description of the Third Phase of OECD/NEA ATLAS International Joint Project

Kyoung Ho Kang

Jongrok Kim, Byoung Uhn Bae, Jae Bong Lee, Yusun Park, Seok Cho, Nam Hyun Choi

2021.05.13.

Korea Atomic Energy Research Institute

CONTENTS

01 OVERVIEW

02 PROPOSED TEST MATRIX

03 OVERALL TEST PLAN

04 SUMMARY

01 OVERVIEW

01 OVERVIEW (1)

- During the past three decades, a number of integral effect test (IET) facilities have been constructed and successfully operated around the world.
  - The overall system behaviors and the related phenomena during the accident transients can be investigated by performing a well-designed IET.
- Within the context of the OECD/NEA ATLAS Phase 2 Project (2017.10 ~ 2020.12), a series of tests were performed to resolve key thermal-hydraulic safety issues related to multiple high-risk failures by using the ATLAS facility.
  - Provide a unique database for validation of system-scale safety analysis codes
  - Contribute to understanding of thermal-hydraulic phenomena during the multiple high-risk failures
- Notwithstanding the distinguished achievement of the OECD/NEA ATLAS Phase 2 Project, a general consensus between the Project partners was reached to continue the third phase of the project.

Project Overview

- **Period**
  - January 1, 2021 ~ December 31, 2024 (4 years)
  - 1st PRG/MB meeting : April 20~22, 2021 (Video conference)
- **Budget**
  - 4.0 million Euro
- **Promising project partners**
  - Belgium (BelV, Tractabel), China (SPICRI, NPIC, CNPRI), Czech (UJV), France (EDF, CEA), Germany (GRS), Spain (CSN), Switzerland (PSI), UAE (FANR), USA (NRC), Korea (KAERI, KINS, KHNP CRI, KEPCO E&C, KEPCO NF, DOOSAN) ➔ 10 countries, 19 organizations
- **Number of tests: 10 tests on 5 topics are planned to be done by reflecting interests of the project participants.**

01 OVERVIEW (3)

» Objectives

- **Establish an IET DB for safety analysis code validation and for assessment of thermal hydraulic behaviors focused on the following safety issues;**
  - Reactor coolant system – containment integrated IET for evaluation of containment thermal-hydraulic safety and performance of safety systems
  - Evaluation of cooling performance of passive safety systems and prediction capability of system-scale safety analysis code against passive safety systems having weak driving force
  - Examination on thermal-hydraulic behavior under asymmetric natural circulation
  - Evaluation of light water reactor safety for DECs focused on the accident management strategy

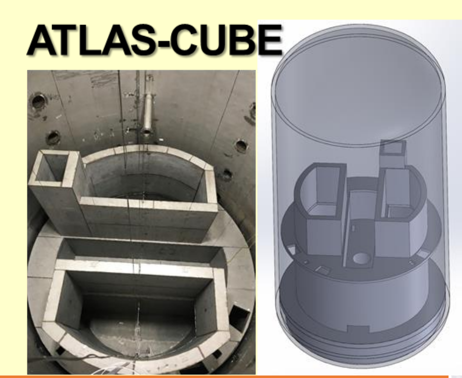
- **Address the scaling issues by performing the counterpart tests**
  - Enhancement of reliability of safety analysis methodology

02
PROPOSED TEST MATRIX

Test Matrix

Topics	Number of tests	Remarks
C1-RCS-CTMT Integrated IET - SLB with ATLAS-CUBE - LOCA with ATLAS-CUBE	 1 1	Interactive phenomena between RCS and containment (CTMT); Evaluation of multi-D phenomena inside the containment and cooling performance of spray system
C2-Passive Safety Systems - SBLOCA with PECCS - IBLOCA with PECCS - SLB with PAFS	 1 1 1	Validation for performance of passive safety systems and related thermal-hydraulic phenomena
C3-Natural Circulation - Asymmetric Natural Circulation	 1	Effect of asymmetric natural circulation on cooldown
C4-Design Extension Conditions - SBLOCA under SBO Condition - Total Loss of Heat Sink	 1 1	Evaluation of the accident management strategy under the multiple failure condition; Effectiveness of PAFS on a shutdown operation
C5-Open Test - Counterpart Test, etc.	 2	Addressing the scaling issue or resolution of safety issues
Total	**10**	

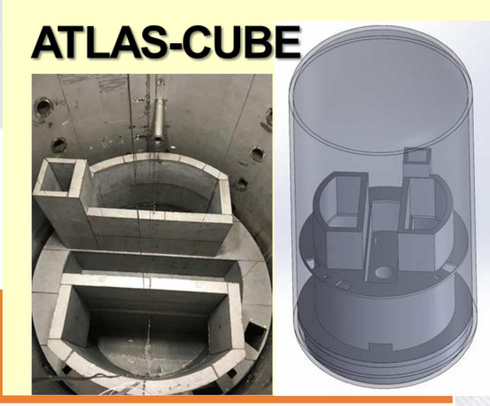
02 C1.1: SLB with ATLAS-CUBE



Summary of Proposed Test: C1.1

Item	Contents
Objectives	▪ To investigate interactive phenomena between the RCS and containment during an SLB transient ▪ To Evaluate multi-dimensional phenomena inside the containment and a cooling capability of passive heat sink and spray system
Critical Measurement Parameters	▪ Asymmetric cooling by SLB in RCS ▪ Temperature distribution of fluid and compartment inside CUBE ▪ Indirect measurement of overall condensation in the containment ▪ Thermal mixing in the containment with spray
Applications	▪ Safety analysis code validation for both of RCS and containment during an SLB transient
Test Matrix	▪ Scenario: Steam line break with ATLAS-CUBE ✓ Guillotine break of steam line from SG-1 ✓ Interconnection of the RCS and containment simulation vessel ✓ Direction of the discharge break pipe: Up or downward ✓ Delayed activation of containment spray system

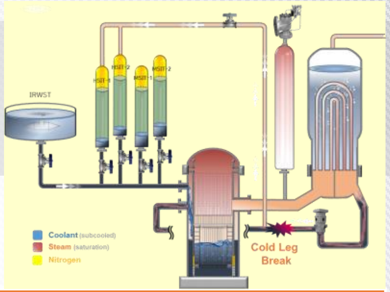
02 C1.2: IBLOCA with ATLAS-CUBE



Summary of Proposed Test: C1.2

Item	Contents
Objectives	▪ To investigate of interactive phenomena between the RCS and containment during the design basis accident ▪ Evaluation of multi-dimensional phenomena inside the containment and cooling capability of passive heat sink and spray system
Critical Measurement Parameters	▪ Pressure build-up in the containment simulation vessel ▪ Temperature distribution of fluid and compartment inside CUBE ▪ Condensation and thermal mixing in the containment w/ spray
Applications	▪ Safety analysis code validation for both of RCS and containment during the design basis accident
Test Matrix	▪ Scenario: Intermediate-size cold leg break with ATLAS-CUBE ✓ 16.4% CL break with interconnecting to the containment simulation vessel in the ATLAS-CUBE ✓ Maximum ECC injection condition for a conservative condition in the containment ✓ Single failure of the containment spray system

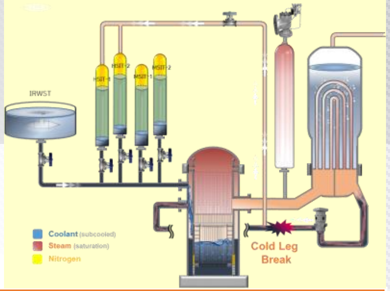
02 C2.1: SBLOCA with PECCS



Summary of Proposed Test: C2.1

Item	Contents
Objectives	▪ To investigate a cooling performance of passive features for a system sustainability during simultaneous small break of top and bottom ICI nozzles of RPV
Critical Measurement parameters	▪ Pressure and temperature variation of the primary system ▪ Collapsed water levels at the major components (RPV, SG, PZR, HPSITs) ▪ Injection flow rate from HPSITs and SITs
Applications	▪ Safety analysis code validation ▪ Phenomena identification through comparison with those of B2.2 of OECD-ATLAS2 project
Test Matrix	▪ Scenario: Top and Bottom nozzle (simultaneous) break ✓ Break of In-Core temperature conduit at the top head (2”) ✓ Break of In-Core neutron flux penetration tube at the bottom head (2”) ▪ Part of PECCS are available (2 HPSITs and 2 SITs, ADV #1 and #2, along with simulated low pressure safety injection from IRWST) ▪ All SIPs are unavailable

02 C2.2: IBLOCA with PECCS



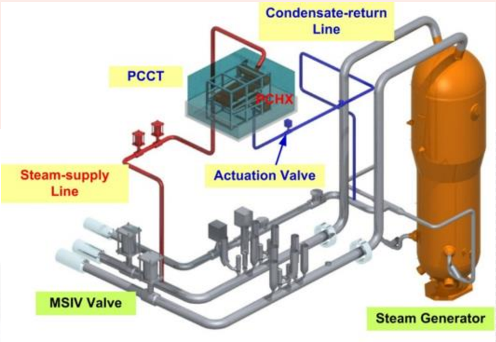
Summary of Proposed Test: C2.2

Item	Contents
Objectives	▪ To expand the database for an IBLOCA simulation with varying the break size and location ▪ To validate the performance of advanced safety system during an IBLOCA scenario
Critical Measurement parameters	▪ Pressure and coolant inventory in the RCS ▪ Integrated mass of the break flow ▪ Maximum cladding temperature in the core ▪ Natural circulation flow rate and fluid temperatures of each loop
Applications	▪ Extension of DB for understanding thermal-hydraulic phenomena during an IBLOCA ▪ Evaluation of current design of safety system to cope with the IBLOCA transient ▪ Safety analysis code validation for predicting IBLOCA phenomena and multi-dimensional behavior ▪ Evaluation of scaling methodology with comparing other IET data
Test Matrix	▪ Scenario: 13 % IBLOCA at cold leg ✓ Passive safety injection by utilizing PECCS ✓ Evaluation of cooling capability of SITs (H-SIT & M-SIT) in innovative PWR ✓ Comparison of effectiveness of the safety injection for core cool down

02 C2.3: SLB with PAFS

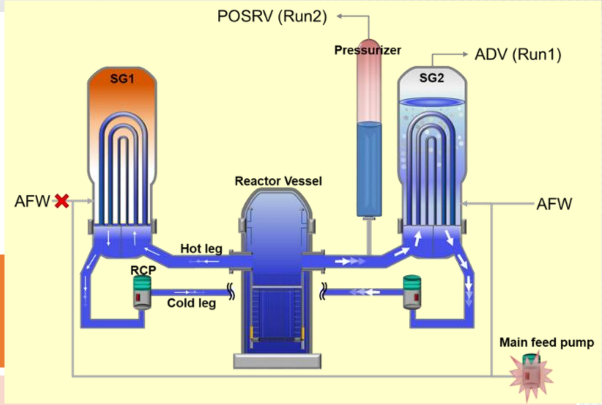
Summary of Proposed Test: C2.3

Item	Contents
Objectives	▪ To investigate a cooling performance of passive features for a system sustainability during a steam line break accident ▪ To provide IET DB on passive cooling system for validating the system codes
Critical Measurement parameters	▪ Natural circulation flow rate and fluid temperatures of each loop ▪ Break flow rate from steam line break ▪ Mixing and flow separation at SG plena ▪ Overall heat transfer coefficient of PAFS HX and natural circulation flow rate and temperature profile in a large water pool
Applications	▪ To evaluate the predicting capability of system codes for the passive residual heat removal system
Test Matrix	▪ Scenario: Steam line break ✓ 1 train of PAFS will be utilized



02 C3.1: Asymmetric Natural Circulation

Summary of Proposed Test: C3.1

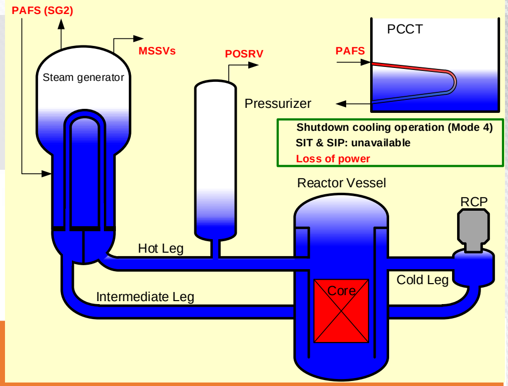


Item	Contents
Objectives	▪ To investigate the natural circulation flow during asymmetric cooling condition ▪ To provide IET DB on asymmetric cooling for validating the system codes
Critical Measurement Parameters	▪ Natural circulation flow rate and fluid temperatures of each loop ▪ Boiling in hot U-tube and Natural circulation stagnation ▪ Flow stagnation in the U-tubes
Applications	▪ Safety analysis code validation ▪ Validation of optimal cool-down rate
Test Matrix	▪ Scenario: 1) One SG isolation with constant RCS pressure (Run 1) 2) One SG isolation with steam release through PZR (Run 2)

Summary of Proposed Test: C4.1

Item	Contents
Objectives	▪ To investigate thermal hydraulic phenomena during a multiple failure accident ▪ To evaluate the effectiveness and system response of an accident management actions ▪ To expand the database for various multiple failure transient conditions
Critical Measurement parameters	▪ Thermal hydraulic parameters in the RCS ▪ Temperature behavior of fuel cladding surface ▪ Integrated mass of the break flow ▪ Natural circulation flow behavior and asymmetry cooling phenomena
Applications	▪ Extension of database for various multiple failure transient condition ▪ Evaluation of the accident management strategy in the multiple failure condition ▪ Safety analysis system code validation
Test Matrix	▪ Scenario: SBLOCA under SBO condition ✓ Secondary system bleed with MSSV operation ✓ SBLOCA when the secondary system of SG is depleted. ✓ SIT injection by primary system pressure depressurization ✓ Secondary system depressurization with feed operation (as an active AM measures at a certain condition (ex: CET or PCT limit))

02 C4.2: Total Loss of Heat Sink



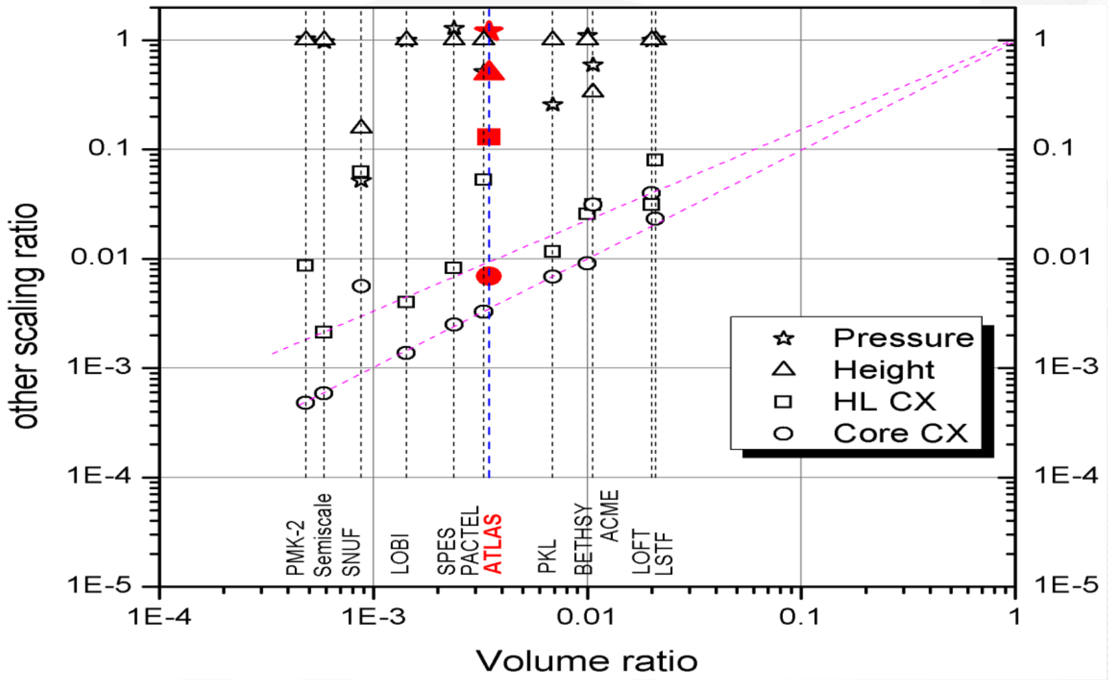
Summary of Proposed Test: C4.2

Item	Contents
Objectives	▪ Investigation of a heat transfer mechanism at low temperature and pressure considering effect of natural circulation on the primary loop and the passive secondary heat removal systems ▪ Evaluation of the grace period on the total loss of heat sink due to loss of power during shutdown cooling operation
Critical Measurement Parameters	▪ Natural circulation flow rate and fluid temperatures of each loop ▪ Temperature distribution inside SG and RPV down-comer ▪ Collapsed water levels and temperatures inside of primary loop, SG, and PAFS
Applications	▪ Safety analysis code validation ▪ Assessment effectiveness of measure of PAFS on a total loss of heat sink during shutdown cooling operation
Test Matrix	▪ Scenario: Total loss of heat sink accident ✓ Loss of power during a shutdown cooling operation ✓ Depressurization: Primary - POSRV / Secondary - MSSVs ✓ PAFS operation on SG-2 ✓ All SIPs and SIT are unavailable

02 C5: Open Items

Summary of Proposed Test: C5

- Address the scaling issues by performing counterpart tests
- Open for any test item considering the interests from the participants



03

OVERALL TEST PLAN

03 OVERALL TEST PLAN

Overall Test Plan (Tentative)

- : Pre-test Analysis
- : Post-test Analysis
- : Test
- : PRG/MB Meeting

Tests	2021	2022	2023	2024	# of tests
C1-RCS-CTMT Integrated IET					
(C1.1) SLB with ATLAS-CUBE					1
(C1.2) IBLOCA with ATLAS-CUBE					1
C2-Passive Safety Systems					
(C2.1) SBLOCA with PECCS					1
(C2.2) IBLOCA with PECCS					1
(C2.3) SLB with PAFS					1
C3-Natural Circulation					
(C3.1) Asymmetric Natural Circulation					1
C4-Design Extension Conditions					
(C4.1) SBLOCA under SBO condition					1
(C4.2) Total Loss of Heat Sink					1
C5-Open Item					
(C5.1) Open item #1					1
(C5.2) Open item #2					1
Total	1, 2	3, 4	5, 6	7, 8	**10**

04
SUMMARY

04 SUMMARY

- The third phase of OECD/NEA joint project utilizing an integral effect test facility of ATLAS has been being operated from January 2021 to December 2024.

- The present OECD/NEA ATLAS-3 project aims at
  - Resolving the raised safety issues
  - Enhancing the physical understanding for multi-D phenomena
  - Validating safety analysis codes

- Utilizing the established IET database, simulation models and methods for complex phenomena of high safety relevance to thermal-hydraulic transients in DBA and BDBA will be validated.

THANK YOU