Integral Effect Test Coupling Reactor Coolant System (RCS) and Containment for Direct Vessel Injection (DVI) Line Break Loss-of-Coolant-Accident (IBLOCA)

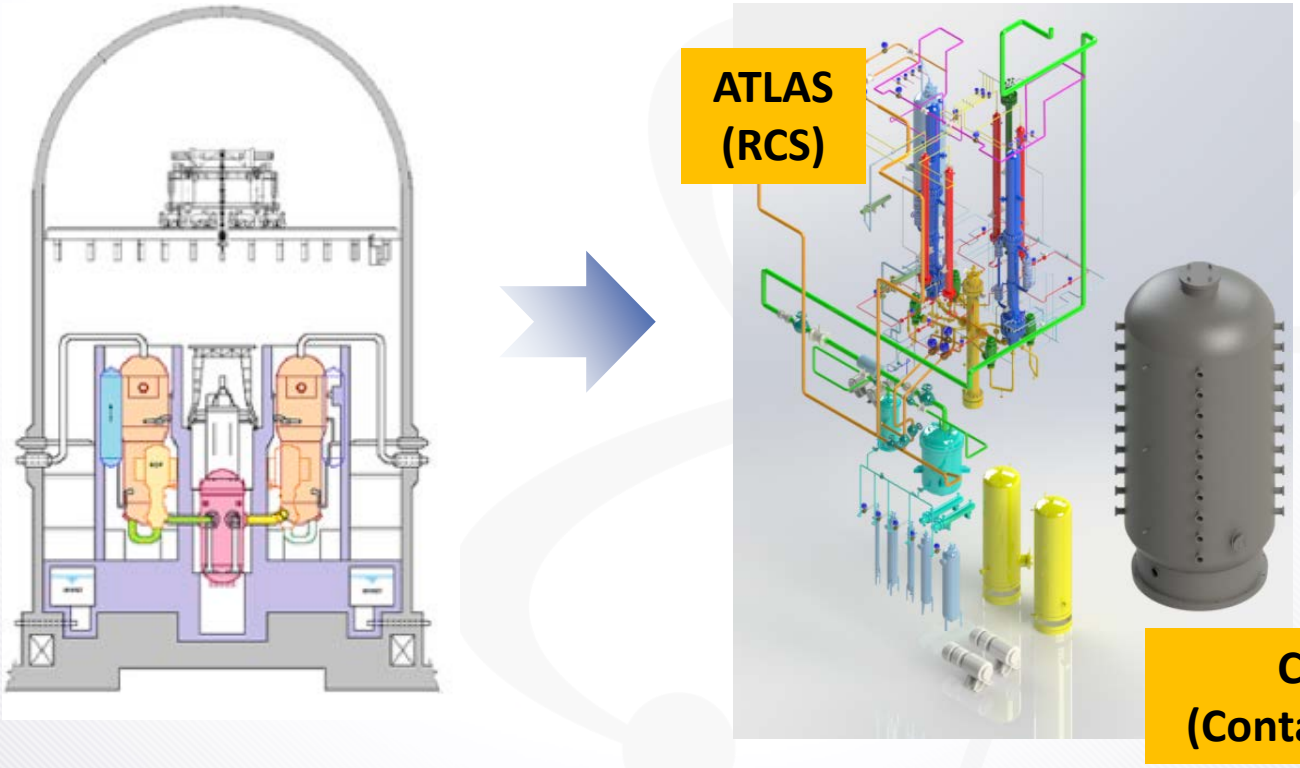
2021. 5. 12 ~ 5. 14

Byoung-Uhn Bae, Jae-Bong Lee, Yu-Sun Park, Jong-Rok Kim,
Seok Cho, Nam-Hyun Choi, Kyoung-Ho Kang

Korea Atomic Energy Research Institute

Overview

- **ATLAS-CUBE**
  - Advanced Thermal-Hydraulic Test Loop for Accident Simulation Containment Utility for Best-estimate Evaluation



01 INTRODUCTION

Objectives of ATLAS-CUBE

- Integral effect test on thermal-hydraulic interaction between RCS (Reactor Coolant System) and containment
- Validation for evaluation methodology
  - M/E (Mass/Energy) release from the RCS
  - P/T (Pressure/Temperature) behavior in the containment
- Validation of containment analysis codes and models

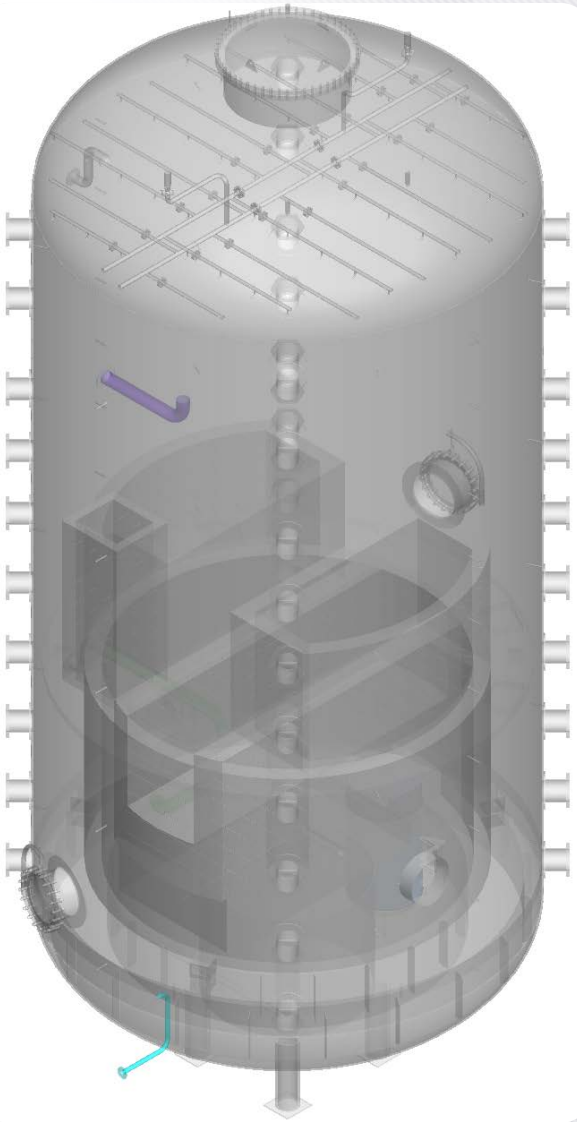
Scope of Study

- Integral effect test on the DVI (Direct Vessel Injection) line IBLOCA (Intermediate Break Loss-of-Coolant Accident)

02 DESIGN OF ATLAS-CUBE

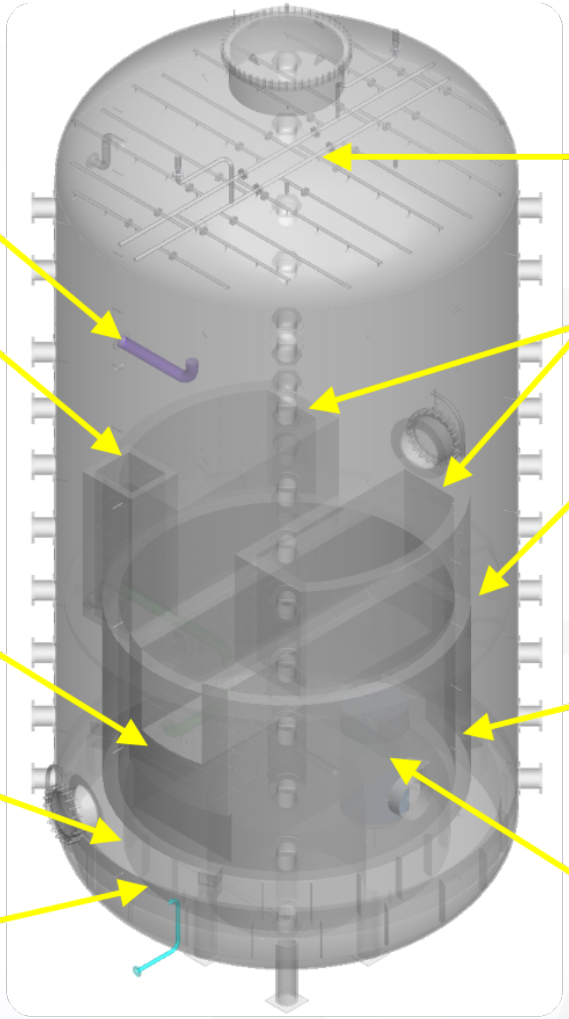
Containment Vessel

- **Containment simulation vessel**
  - Linear scaling methodology with equivalent volume scale of ATLAS (1/288)
  - Diameter: 6 m / Height: 13 m
  - Total volume: 340 m^3
  - Operating pressure: 0.5 MPa
- **Passive heat sink**
  - Conservation of the aspect ratio of the free volume for each compartments
- **Containment spray system**
- **Connection pipe from ATLAS**
  - Break simulation of LOCA and SLB: 6 inch



02 DESIGN OF ATLAS-CUBE

Containment Vessel



Connection Pipe from ATLAS
Break simulation for LOCA and SLB

Pressurizer Compartment
Concrete wall surrounding the pressurizer

Primary Shield Wall (PSW)
Concrete structure house for the reactor pressure vessel as radiation shielding and protector from internal attack
PSW provides a support for the refueling canal wall (Refueling Pool) and penetrations for the primary loop

Pedestal Floor (PF)
Foundation of compartments of CUBE as IRWST upper wall

In-Containment Refueling Water Storage Tank (IRWST)
Water source for SI and containment spray

Containment Spray System
Simulation of active cooling by spray injection from top head of the containment

Steam Generator Compartment
Concrete wall surrounding steam generators

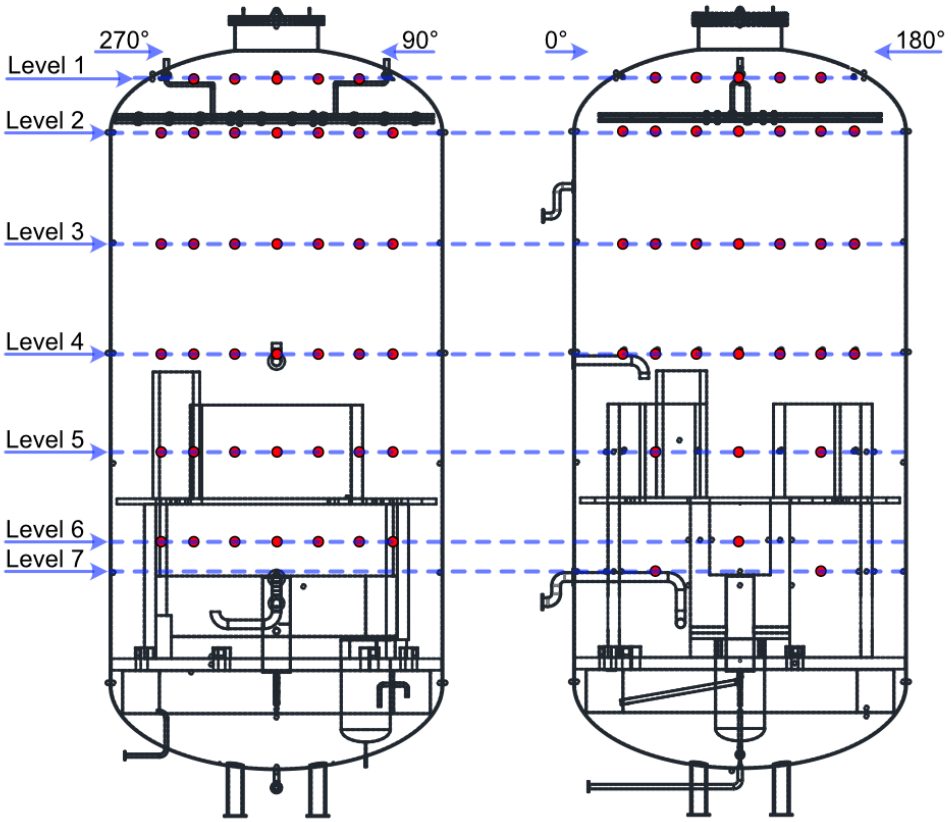
Operating Floor (OF)
Providing access for operating personnel functions and biological shielding

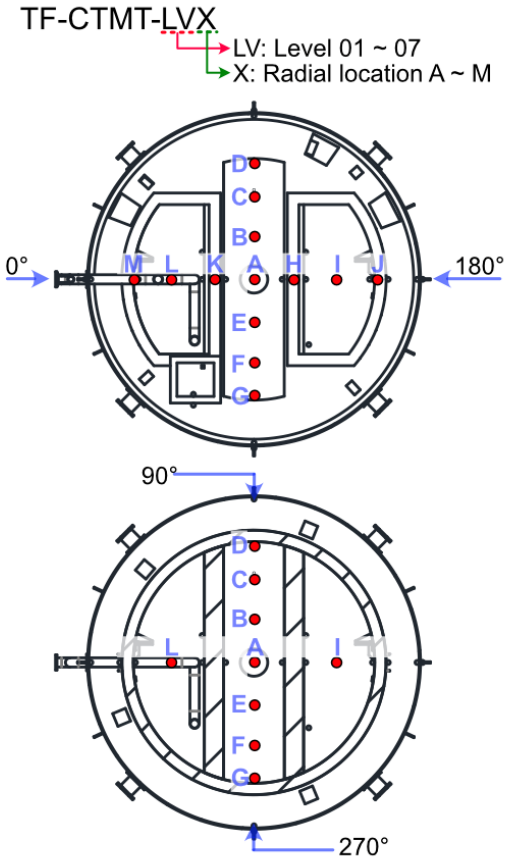
Secondary Shield Wall (SSW)
Concrete structure surrounding steam generators, reactor coolant pump, and pressurizer as a biological shielding for the coolant loop and equipment and structural support

Holdup Volume Tank (HVT)
Colleting and returning water to the IRWST

Instrument and Control System

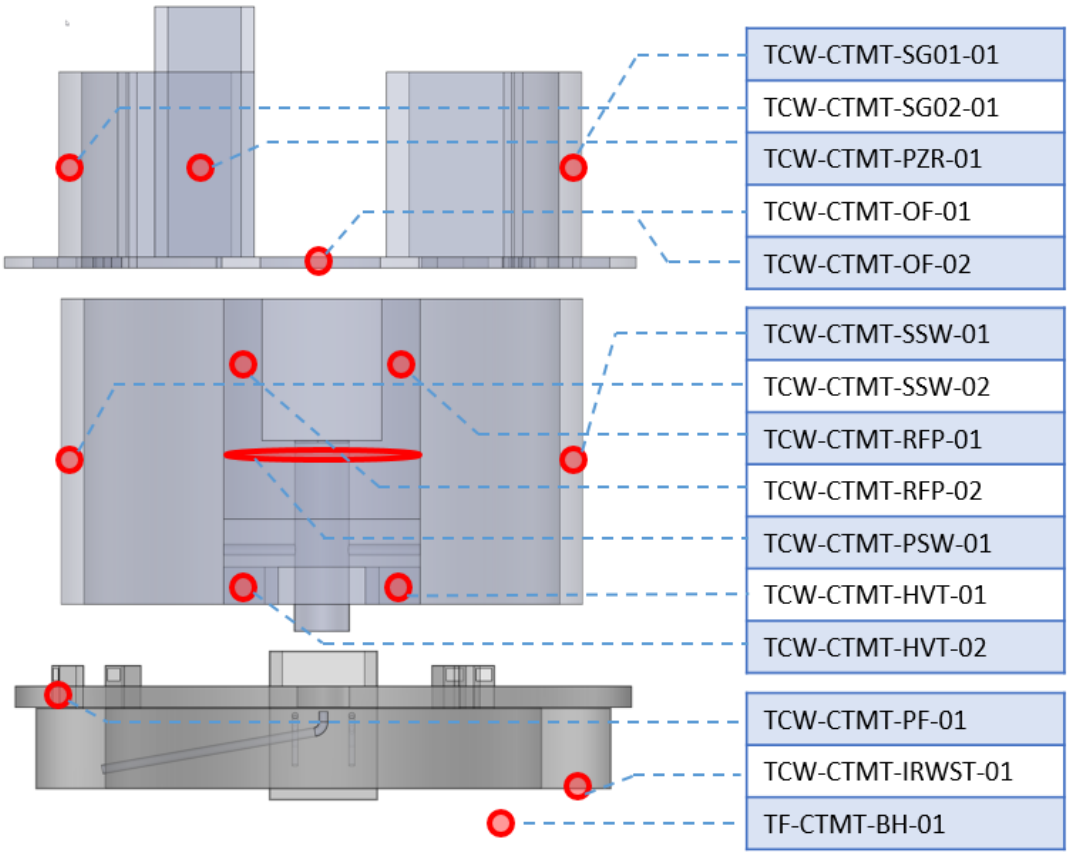
- **Multi-dimensional distribution of fluid temperature**

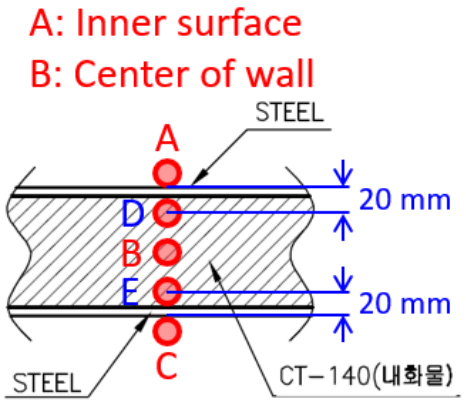




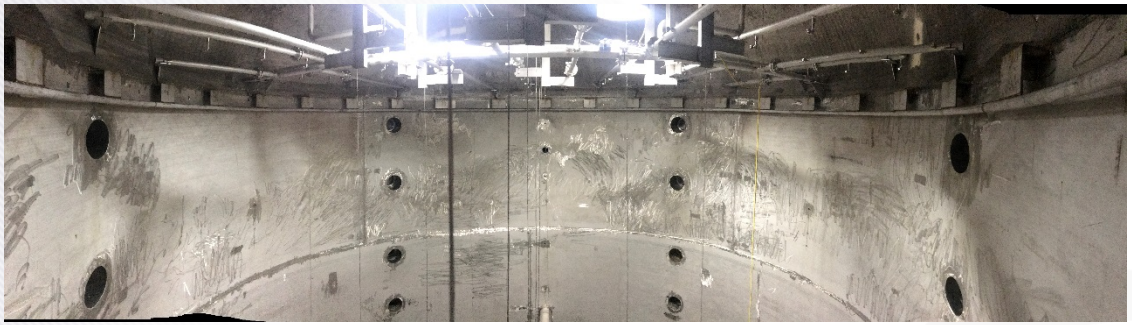
Instrument and Control System

- **Measurement of compartment wall temperature**





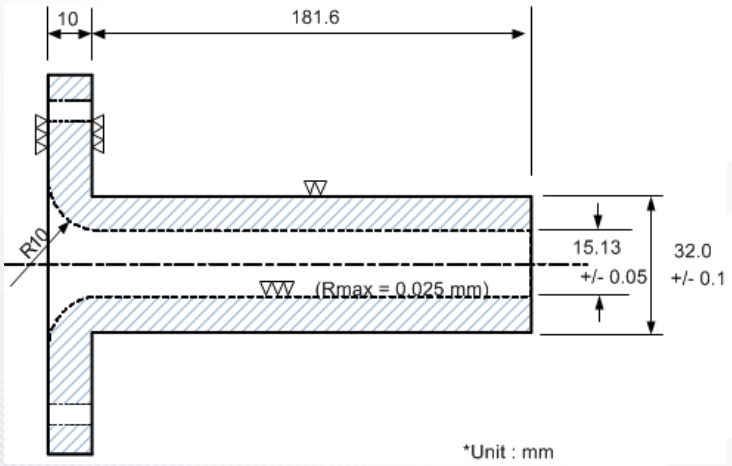
Internal View of Containment Vessel

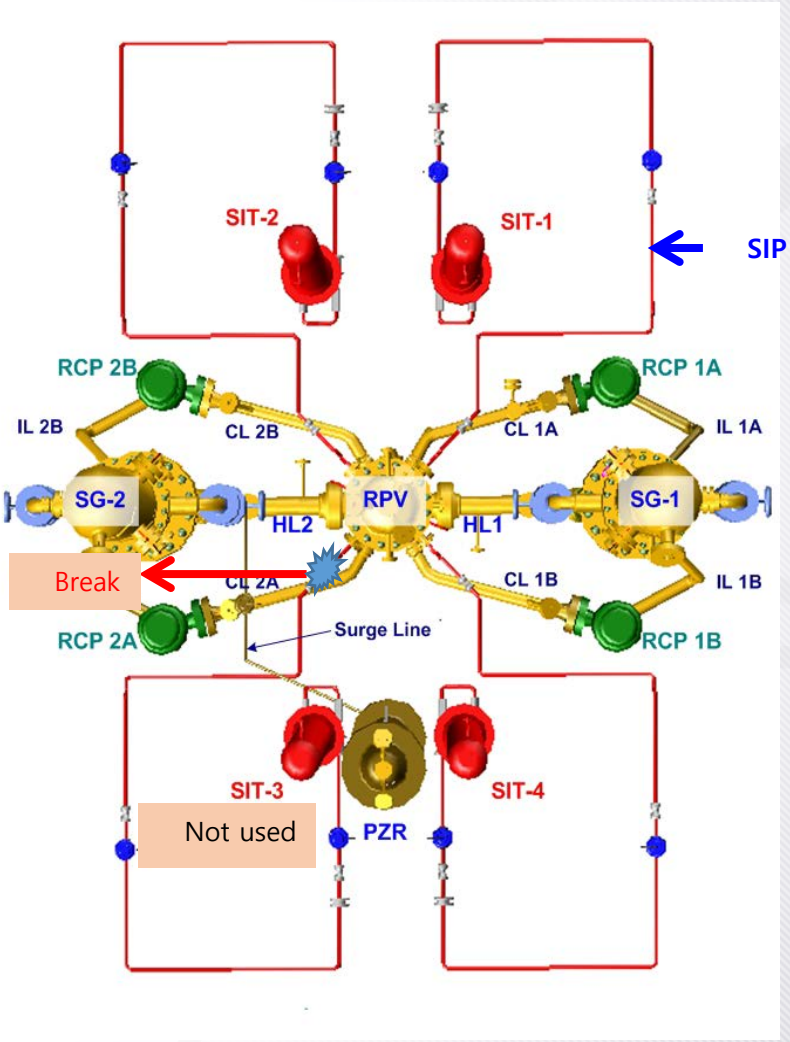


Visualization online (3D VR)
https://youtu.be/KM0NePG2MU4

Test Condition

- **Break area**
  - 100% break of DVI line
  - Break nozzle diameter : 15.13 mm (8.5 inch in APR1400)
  - Corresponding to 8% of cold leg flow area



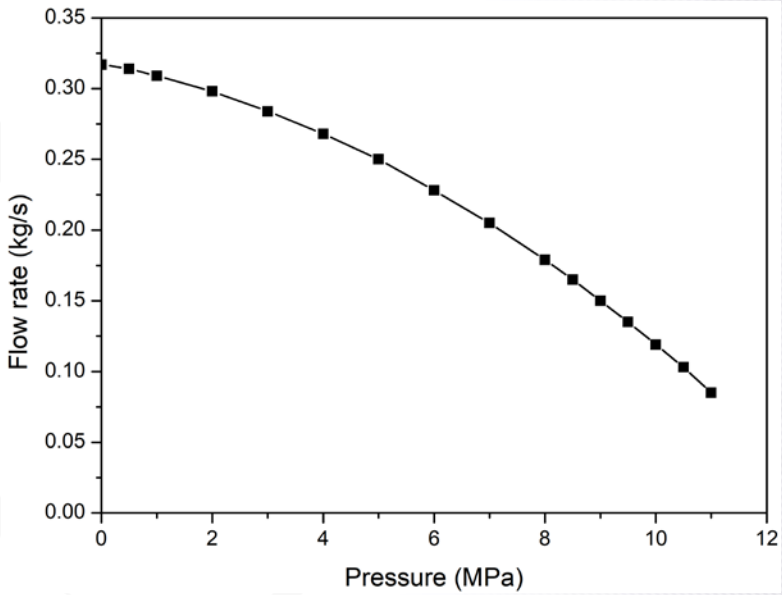


Test Condition

- **Trip set-point**
  - Set-point of LPP signal : 10.72 MPa (PT-PZR-01)
  - Reactor / RCP Trip : LPP signal + 0.0 sec
  - MFIV close : LPP signal + 7.07 sec delay
  - MSIS close : LPP signal + 3.54 sec delay
- **Initiation of safety injection**
  - SIP 1 : LPP Signal + 28.28 sec delay (Assumption of single failure)
  - SIT 1, 2, 4 : Downcomer pressure (PT-DC-01) < 4.03 MPa
- **Secondary system**
  - MSSV : Opening and closing according to the steam dome pressure (8.1 MPa / 7.7 MPa)
  - Auxiliary feedwater to secondary system : Assumed to be not available

Test Condition

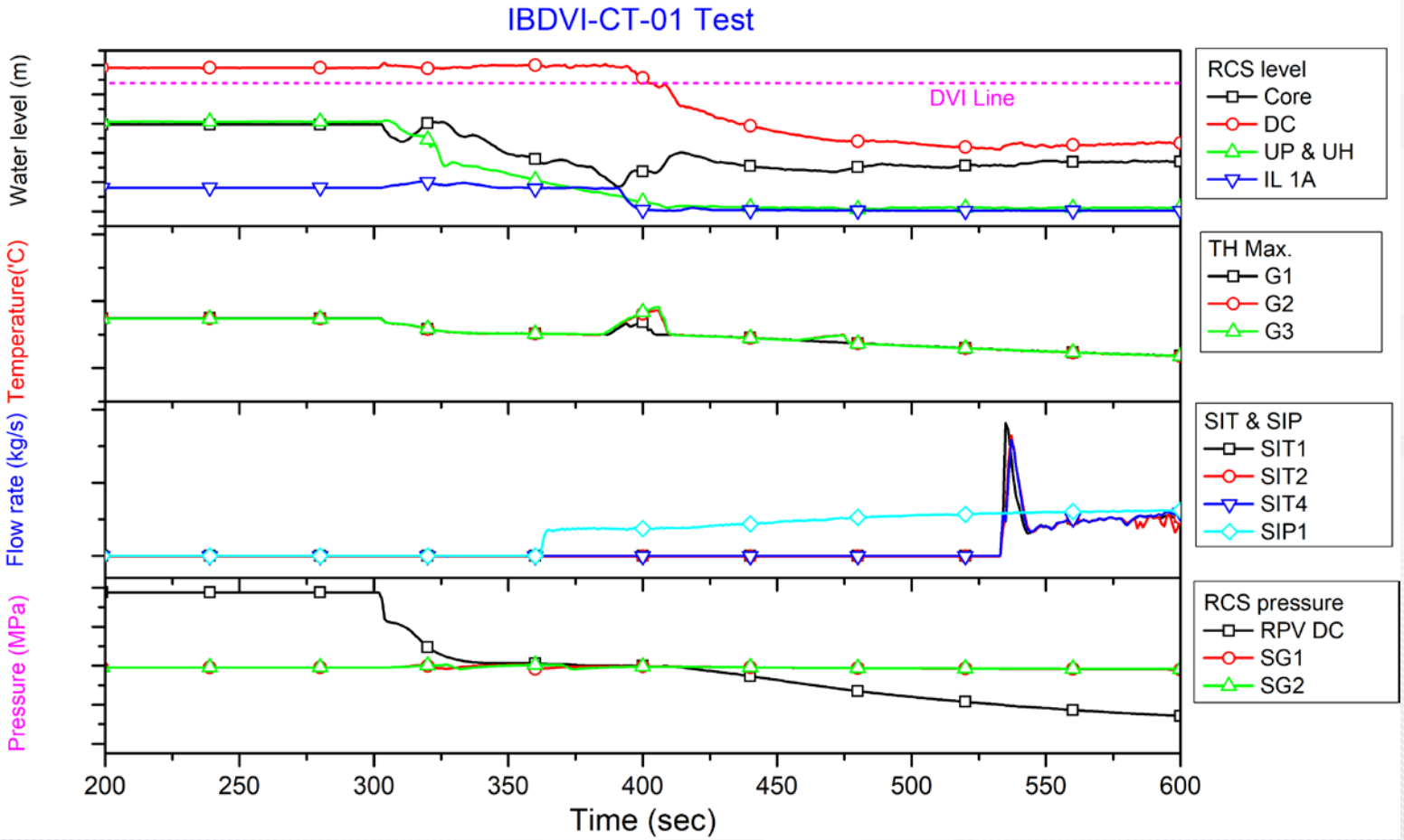
- **Safety injection**
  - 1 SIP and 3 SITs through DVI
- **SIT**
  - Initial condition : 4.3 MPa & 50 °C (Nitrogen & Water)
  - Initial water level : 3.73 m
  - Activation of fluidic device : 2.0 m
  - Termination of SIT injection : 0.10 m
- **SIP**
  - Condition : 0.1 MPa & 50 °C
  - Flow rate curve depending on downcomer pressure



Flow rate curve of a SIP

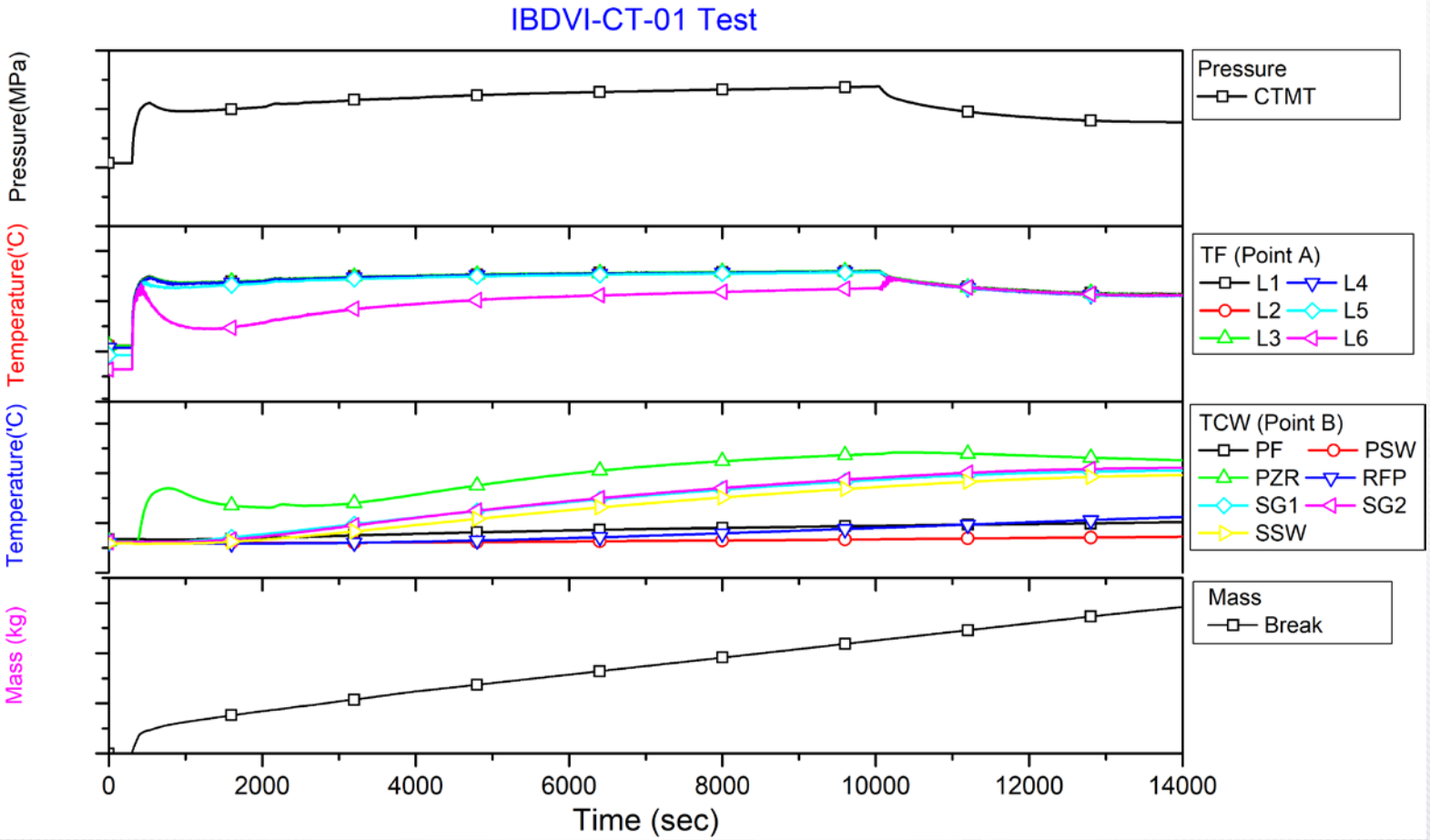
Thermal Hydraulic Behavior in the RCS

- **Core heat-up was quenched by clearance of upper downcomer.**



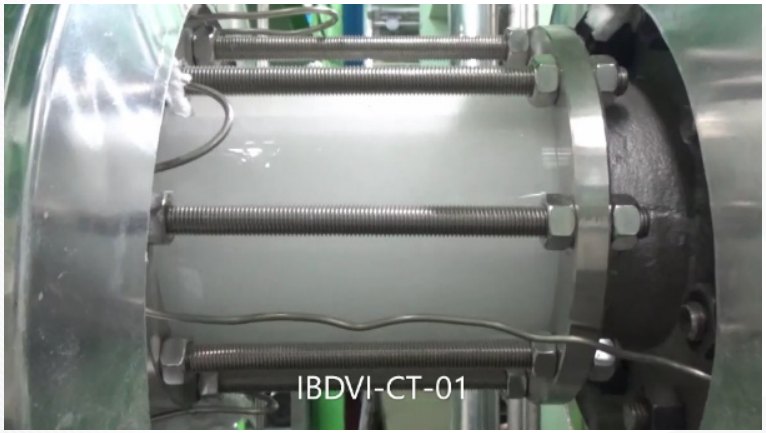
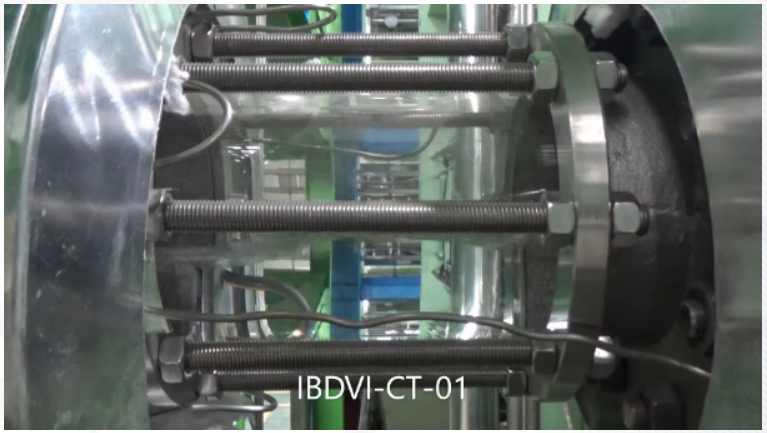
Thermal Hydraulic Behavior in the Containment

- **Build-up of P/T was cooled by passive heat sink and spray system.**



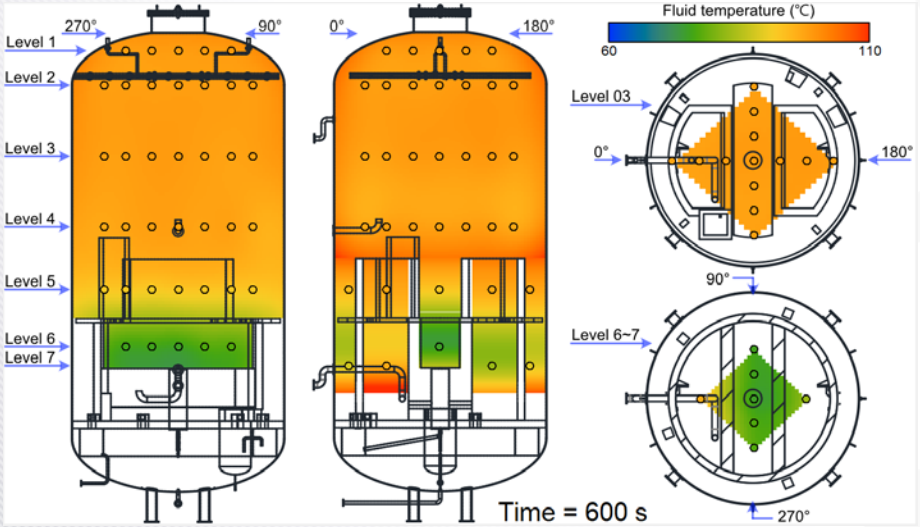
Break flow behavior

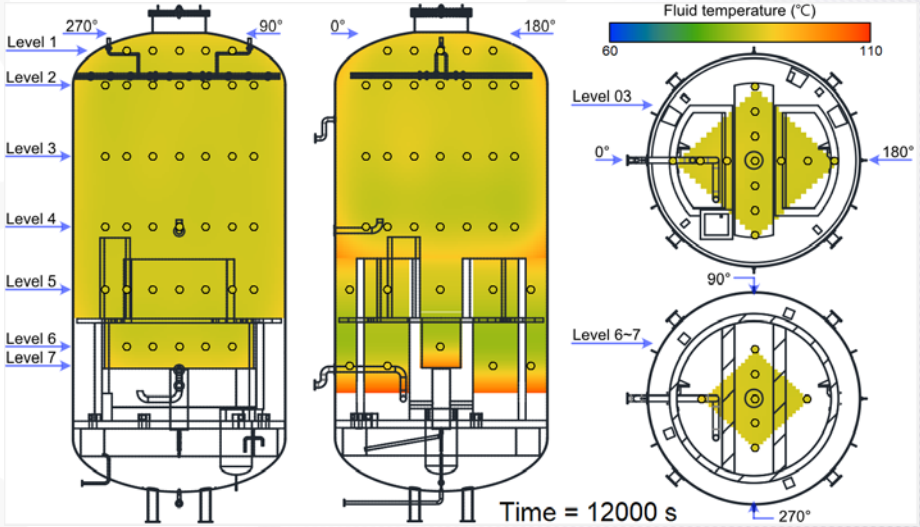
- **A liquid flow with a small subcooling degree existed in the break simulation pipe during most of the transient.**

	
(a) t = 307s (Churn-turbulent flow)	(b) t = 10064s (Stratified flow)

Steam-gas Mixture Temperature in Containment

- At the initial period of the transient, a SG-2 compartment room showed a higher temperature, while the steam-gas mixture in a dome region above the SG compartment rooms was well mixed.
- The spray injection induced more homogeneous temperature field inside the containment by the heat transfer effect between falling droplets and the steam-gas mixture.





Major Findings from the Test

- Both of the RCS and the containment were effectively cooled down during the transient, by activation of the safety injection system and the containment spray system, respectively.
- The M/E supply from the RCS increased a pressure and a steam-gas mixture temperature of the containment, while a wall condensation on the passive heat sink and a spray injection contributed to cool down the steam-gas mixture.
- The asymmetric distribution of the steam-gas mixture and the compartment wall temperatures was observed due to an effect of the break location in the SG-2 compartment room. A containment dome region showed a well-mixed distribution.
- The spray injection induced more homogeneous temperature field inside the containment.

04 CONCLUDING REMARK

Summary

- The IBDVI-CT-01 test was performed by utilizing the ATLAS-CUBE facility to investigate an interactive thermal hydraulic transient of a RCS and a containment during the DVI line break IBLOCA .
- Cooling capability of RCS and containment was evaluated and the multi-dimensional phenomena inside a containment was investigated.

Applications

- Validation of the evaluation methodology for M/E and P/T transient of a reactor containment
- Assessment of the containment analysis code