Inspection and Validation Activities on Severe Accident Management in Korea after the Fukushima Accident

IAEA IEM on Severe Accident Management in the Light of the Accident at the Fukushima Daiichi N.P.P.

17-21 March 2014, Vienna, Austria

Han-Chul Kim*, Jung-Jae Lee, Sung-Han Lee
Korea Institute of Nuclear Safety
(*E-mail: khc@kins.re.kr)

Outline

1. Introduction
2. Special Safety Inspection for Operating Plants in Korea
3. External Cooling Water Injection
4. Confirmatory Analysis of External Cooling Water Injection
5. Conclusions

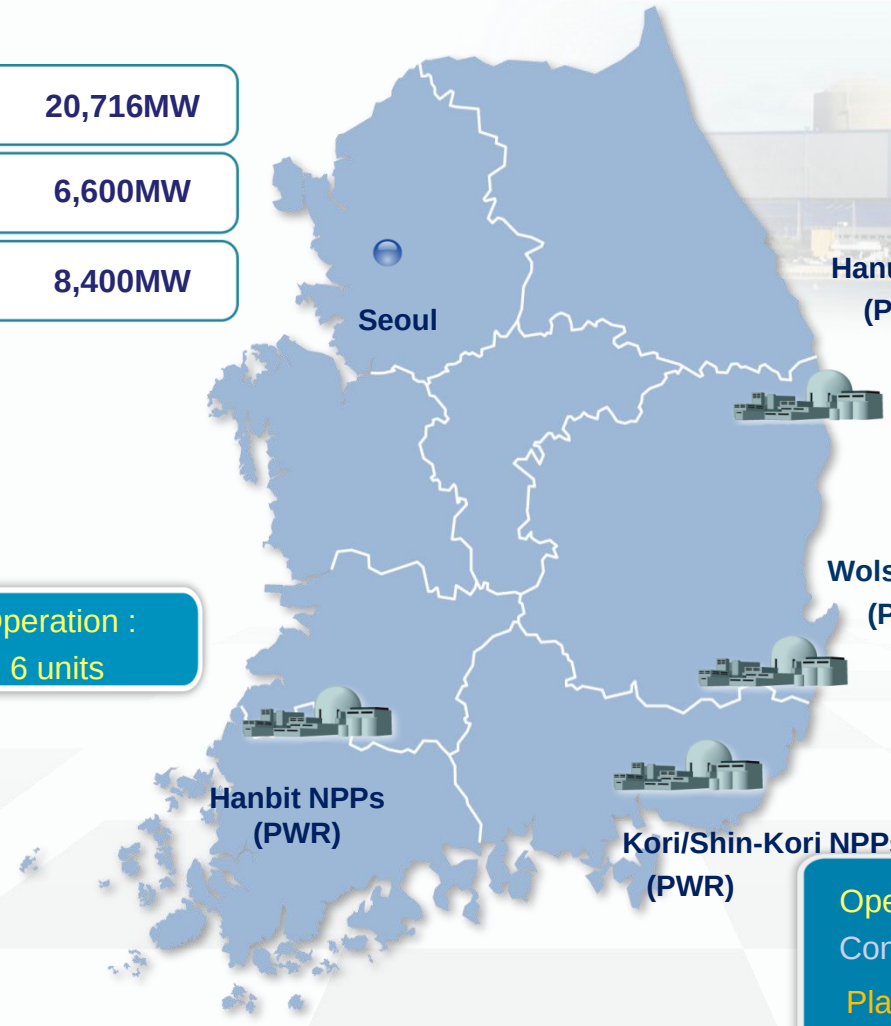
Introduction

- Injection flow paths for emergency cooling water is being installed at the Korean NPPs following the Government order.
  - It was recommended through the Special Safety Inspection
  - The objective is to provide cooling water from external sources to the primary and secondary loops during a prolonged station blackout accident.
- The effectiveness of this strategy needs to be confirmed through evaluation of the installed system and on-site verification.
- This presentation shows the background of this installation and the relevant confirmatory analysis results for APR1400.

Introduction

Status of Nuclear Power Plants in Korea

Operation	23 Units	20,716MW
Construction	5 Units	6,600MW
Planning	6 Units	8,400MW



Special Safety Inspection for Operating Plants in Korea

- A Special Safety Inspection (SSI) was conducted by the Government.
  - Seventy-three inspectors from the regulatory organizations, research institutes, universities, etc. undertook the mission.
  - The assumed scenario mirrored the Fukushima accident:
    earthquake → tsunami → power loss → extreme severe accident
  - They inspected 21 operating NPPs, a research reactor, and fuel cycle facilities for 5 weeks.
    - Site inspection: Mar.21 ~ Apr.15, 2011
    - Review of findings: Apr.16 ~ Apr.30, 2011
  - Hearings for the residents of the nearby towns of NPPs were held before and after the inspection.

Special Safety Inspection for Operating Plants in Korea

❑ Major Inspection Points of SSI

Defense-In-Depth Functions	Major Inspection Points
Extreme Natural Hazards	Adequacy of the plant design and facilities against natural hazards - Design against earthquake and seismic capacity - Design against coastal flooding and inundation protection capability
Prevention of Severe Accidents	Adequacy of power supply and cooling functions - Power system and emergency power supply - Cooling capability in case of station blackout and inundation
Mitigation of Severe Accidents	Adequacy of countermeasures against severe accidents - Facilities, guidelines, and strategies against severe accidents
Emergency Response	Adequacy of emergency response - Emergency response to multi-units accidents - Facilities, systems, and infrastructure for the protection of local residents and workers

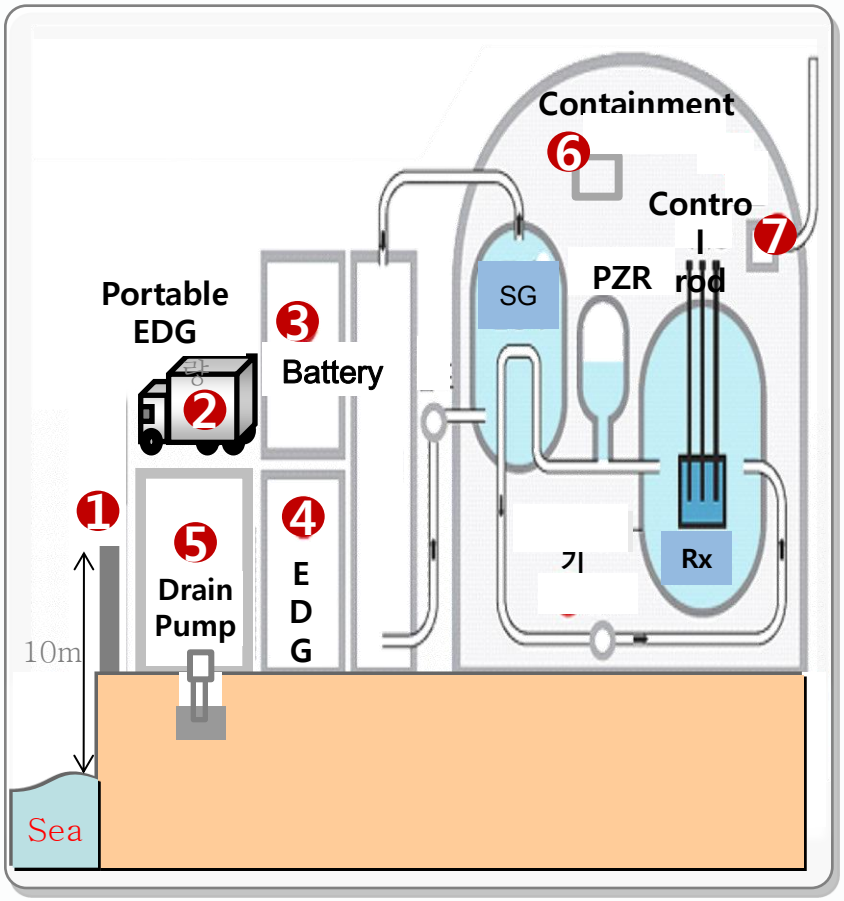
Special Safety Inspection for Operating Plants in Korea

❑ Inspection Results

- ➢ Korean NPPs in operation have no imminent risk for the expected maximum potential earthquake and coastal flooding, based on the up-to-date investigation/research.
- ➢ However, there are needs to implement the long and short-term improvements in order to secure safety for beyond-design-basis natural events

Special Safety Inspection for Operating Plants in Korea

❑ Major Safety Improvements for Korean NPPs



Improvements

1. Making the coastal barrier higher (Kori site)
2. Preparing a vehicle with a portable emergency diesel generator at each site
3. Securing the safety of emergency battery power from flooding
4. Installing watertight doors at major buildings
5. Water-proofing drain pumps
6. Installing passive H_2 removal systems which operate without electricity [PAR]
7. Installing containment filtered vent or an alternative depressurizing system

1 billion USD investment over 5 years

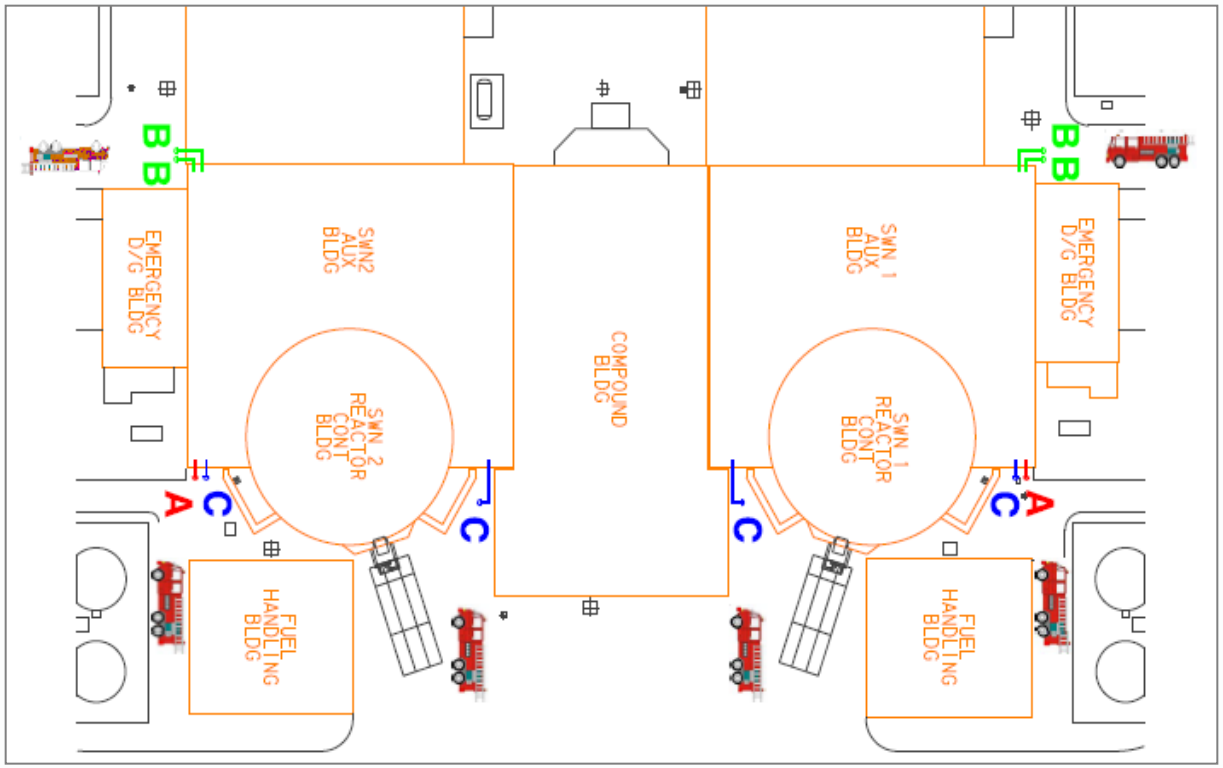
Special Safety Inspection for Operating Plants in Korea

- On-going safety improvements concerning a severe accident

Category		Improvements
Severe Accident Management	Guidelines	Strengthening severe accident education and training
		Revising severe accident management guidelines (SAMGs) to enhance their effectiveness
		Developing low-power and shutdown SAMGs
	Equipment and Facilities	Installation of injection flow paths for emergency cooling water from external sources
		Installation of passive hydrogen removal equipment (PAR)
		Installation of filtered venting system (CFVS) or depressurizing facilities in the containment building

External Cooling Water Injection

❑ External cooling water injection stratgegy



❖ Requirement:

➢ Some alternative, direct lineups to inject emergency water source to the primary and secondary loops should be provided as soon as possible.

An additional line to provide emergency cooling water from outside the reactor containment building to the reactor (A), auxiliary feed tank (B), and steam generator (C) (KHNP plan)

External Cooling Water Injection

- External cooling water for the primary system is injected into the core through the shutdown cooling line.
- Secondary system injection adopts two different ways:
  - Make up the exhausted auxiliary feedwater (AFW) storage tank through a fire engine
  - Inject cooling water directly into the AFW discharge pipe through a branch line using a fire engine
- Injection is possible when RCS or steam generator secondary pressure decreases below 15 kg/cm^2 (1.47 MPa).
- Minimum required injection flow rates were estimated by the utility. Analysis of various accident scenarios including station blackout using MAAP 4.06 showed that they could be achieved.

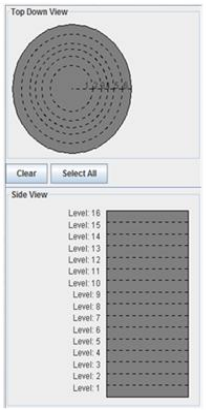
Confirmatory Analysis of Ext. Cooling Water Injection

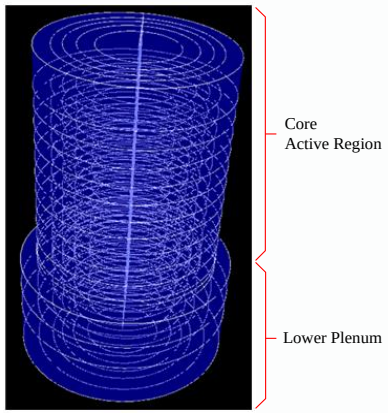
- Accident sequence considered: a SBO with external water injection

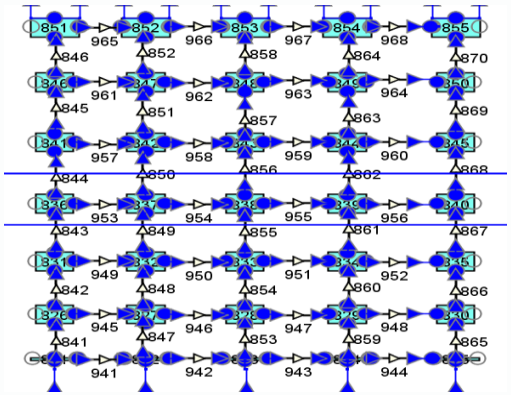
Time (sec)	Event	Remark
0.0	- Reactor Trip - Stop to Supply MFW - Start to Supply TDAFW	
900.0	- RCP Seal Leakage	Failure time assumed
28800.0	- Stop to Supply TDAFW	
30600.0	- ADV Manual Open	30 min. after AFWP trip
Set point : 1st Pressure < 15 kg/cm^2	- Injection into the primary system	Pump performance curve used
Set point : 2nd Pressure < 15 kg/cm^2	- Injection into the secondary system	Pump performance curve used

Confirmatory Analysis of Ext. Cooling Water Injection

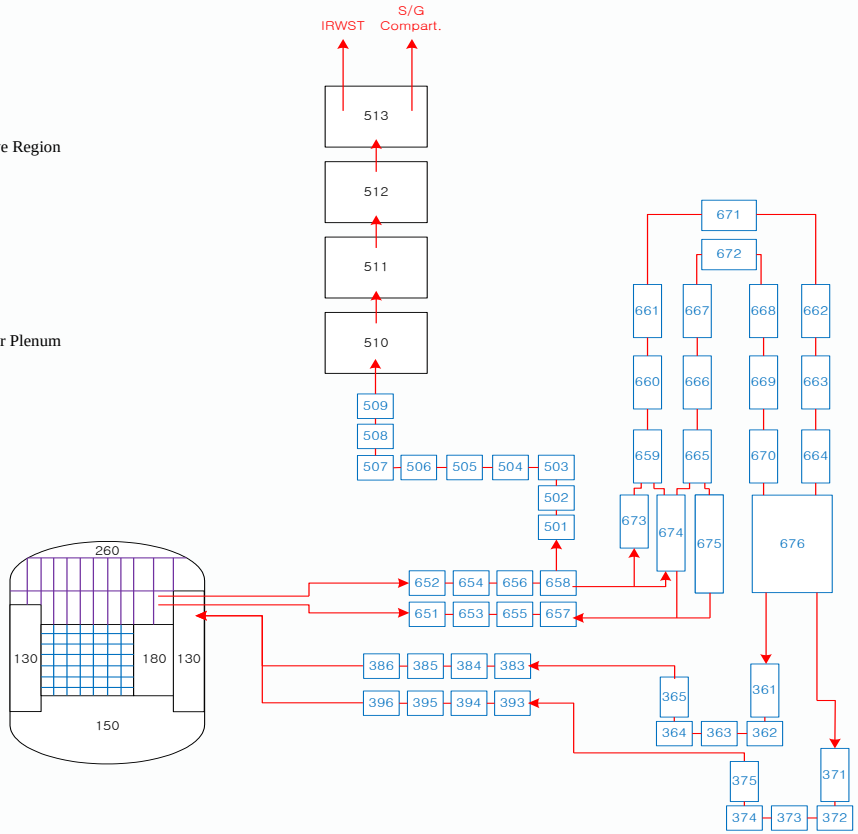
- Reactor core, primary and secondary system model
  - KINS has been developing a MELCOR model with the assistance of a contractor.



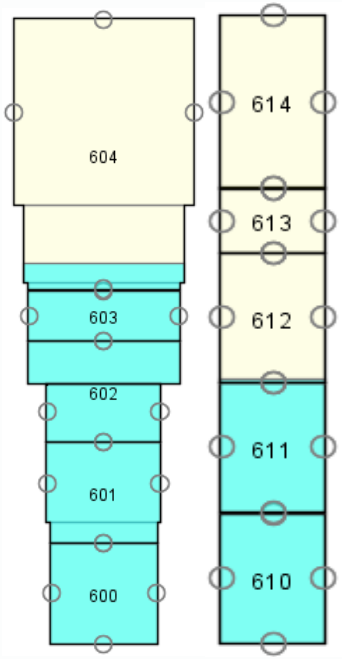




Reactor core



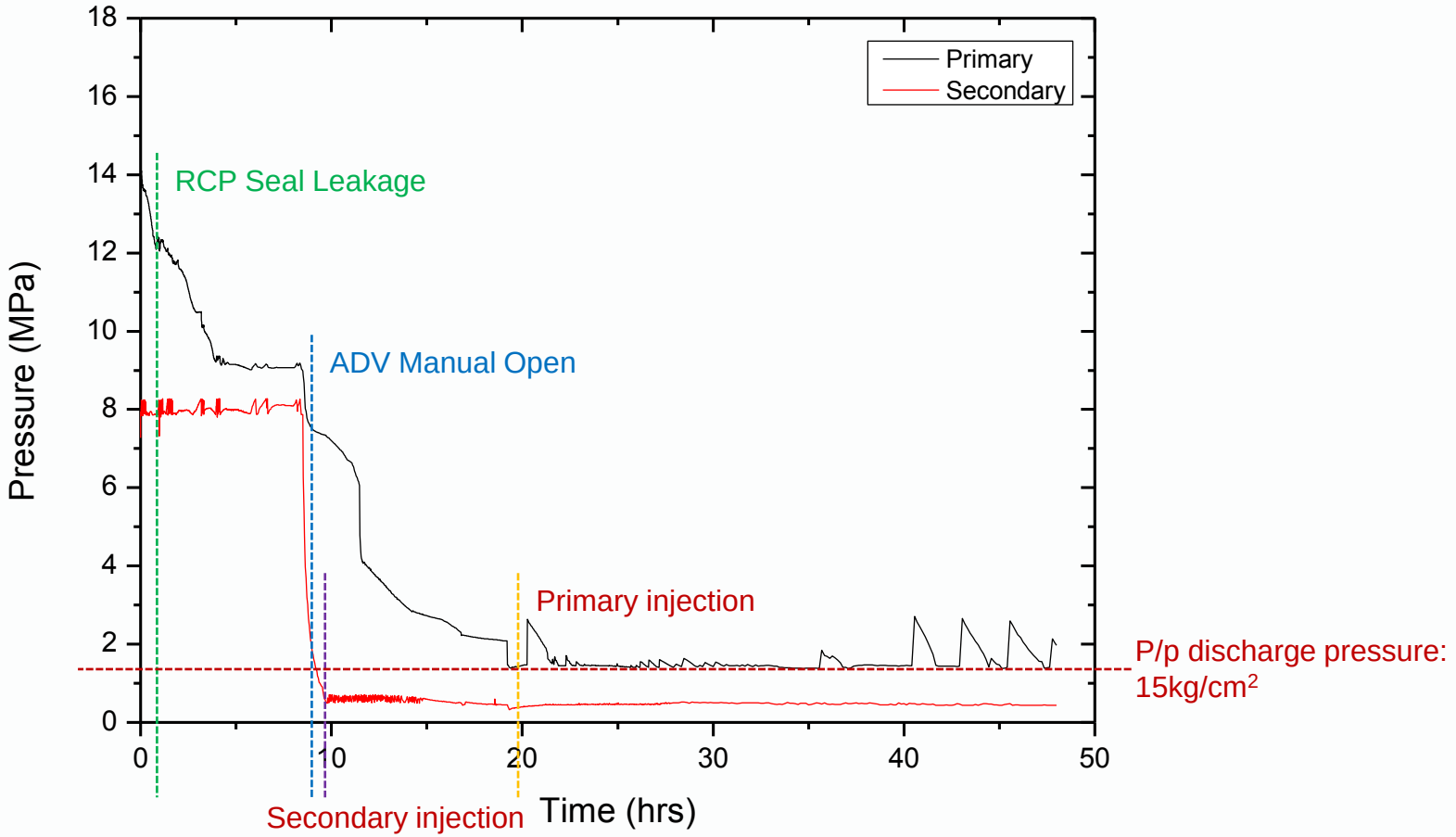
Reactor coolant system



Steam generator secondary side

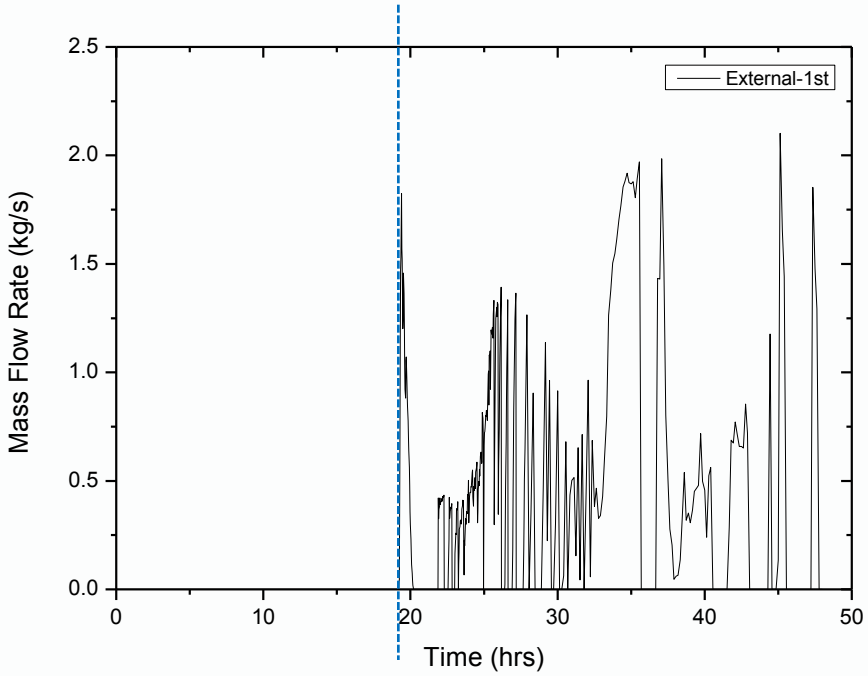
Confirmatory Analysis of Ext. Cooling Water Injection

- Preliminary result: Primary and secondary system pressure change

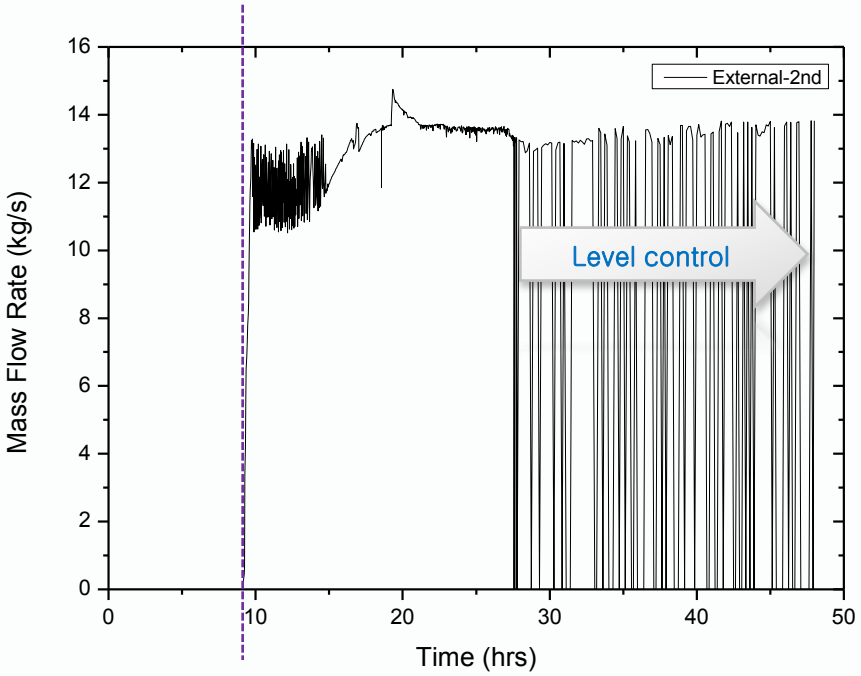


Confirmatory Analysis of Ext. Cooling Water Injection

- Preliminary result: Primary and secondary injection flow rates



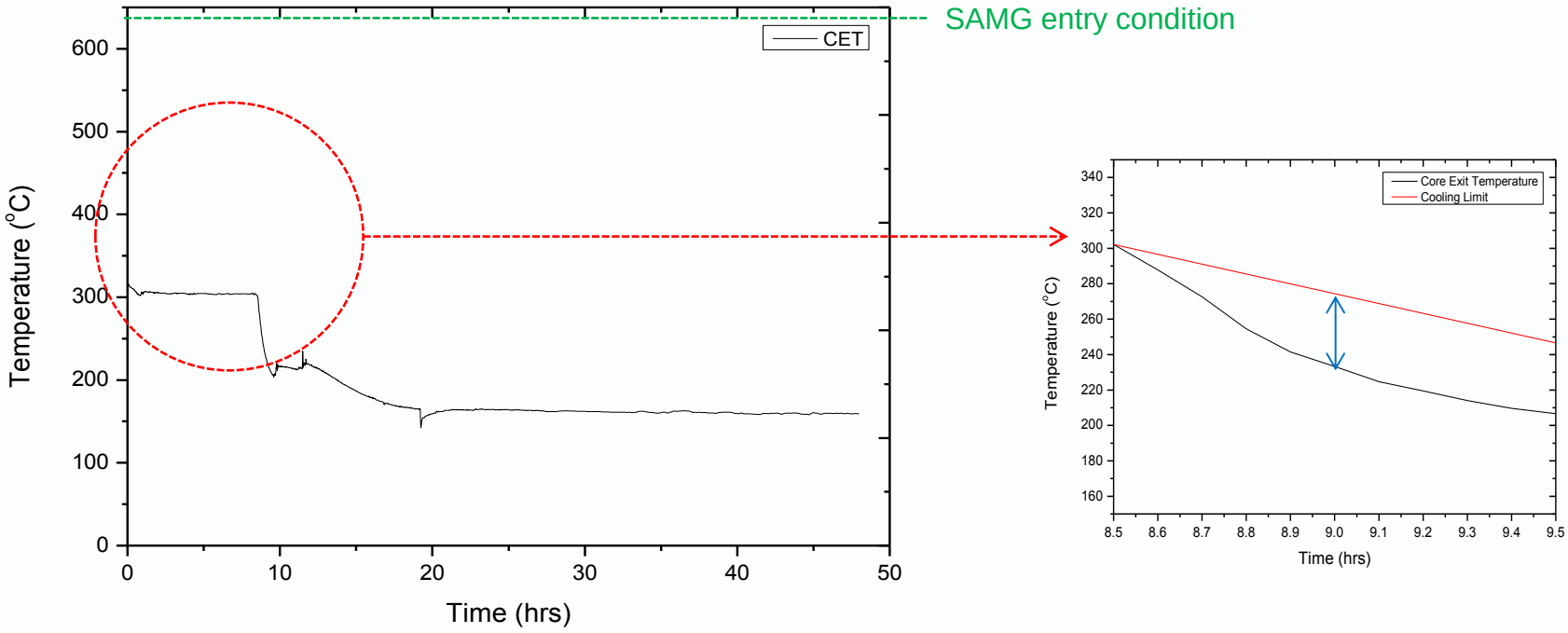
Primary system injection at 19.2 hr



Secondary system injection at 9.1 hr

Confirmatory Analysis of Ext. Cooling Water Injection

- Preliminary result: Core exit temperature
  - Reactor core can be sufficiently cooled with an ADV open.
  - Further consideration will be given to the cooling rate, which is higher than the operation limit, 55.6 ℃/h (100℉/h).



Conclusions

- Injection flow paths for external cooling water are being installed at the Korean NPPs following a special safety inspection.
- A best-estimate MELCOR analysis to check the effectiveness of this strategy is being carried out.
- The preliminary analysis results show that this strategy could successfully cool the reactor core for a station blackout accident through its effective implementation.

Acknowledgments

This work is based on the results from
the Nuclear Safety Research and Development program
of Nuclear Safety and Safeguard Commission.