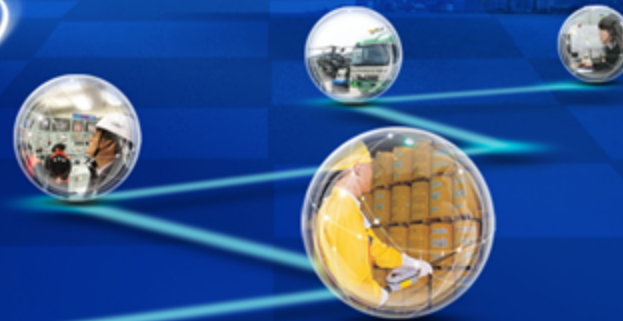


Recent Experience on Aging Degradation in Korea



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Nuclear Power Program in Korea

- **Permanent shutdown: 2 Units**
- **Under construction: 5 Units** (including 1 Unit preparing commercial operation)
- **In operation: 25 Units**
 - **Average age: 24 years**
 - **Average age by reactor type**
 - **Westinghouse (5 Units): 39 years**
 - **Framatome (2 Units): 36 years**
 - **CANDU (3 Units): 26 years**
 - **OPR-1000 (12 Units): 20 years**
 - **APR-1400 (3 Units): 5 years**



Status of Continued Operation (Life Extension)

- **Status of permanent shutdown**

Plant Name	Design life	End of design life	Continued operation	Permanent shutdown
Kori Unit 1	30 Years	Jun. 18, 2007	~ Jun. 18, 2017	Jun. 18, 2017
Wolsong Unit 1	30 Years	Nov. 20, 2012	~ Dec. 24, 2019	Dec. 24, 2019

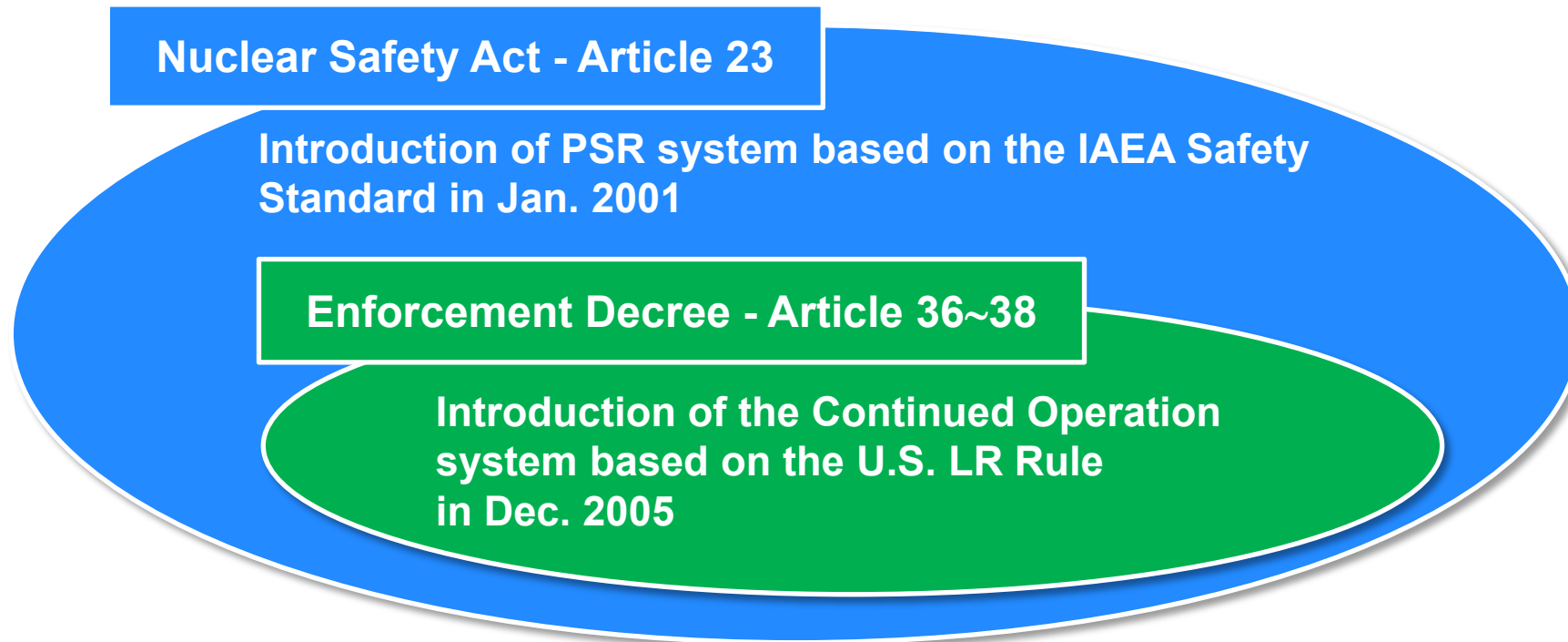
- **Status of the continued operation application**

Plant Name	Design life	End of design life	Application for CO	Safety review	Remarks
Kori Unit 2	40 Years	Apr. 08, 2023	Apr. 4, 2022	Dec. 2, 2023~	
Kori Units 3&4	40 Years	Sep. 28, 2024 Aug. 06, 2025	Sep. 26, 2022	May 12, 2023~	
Hanbit Units 1&2	40 Years	Dec. 22, 2025 Sep. 11, 2026	Jun. 30, 2023		Under docket review
Hanul Units 1&2	40 Years	Dec. 22, 2027 Dec. 28, 2028	Oct. 30, 2023		Under docket review

- It is expected that **10 to 12 nuclear power plants will apply for continued operation by 2030**, including nuclear power plants that have already applied for continued operation.

Regulatory Framework for Continued Operation of NPPs

- A Continued Operation system was introduced under the framework of PSR (Periodic Safety Review) with reference to the U.S. LR (License Renewal) Rule.

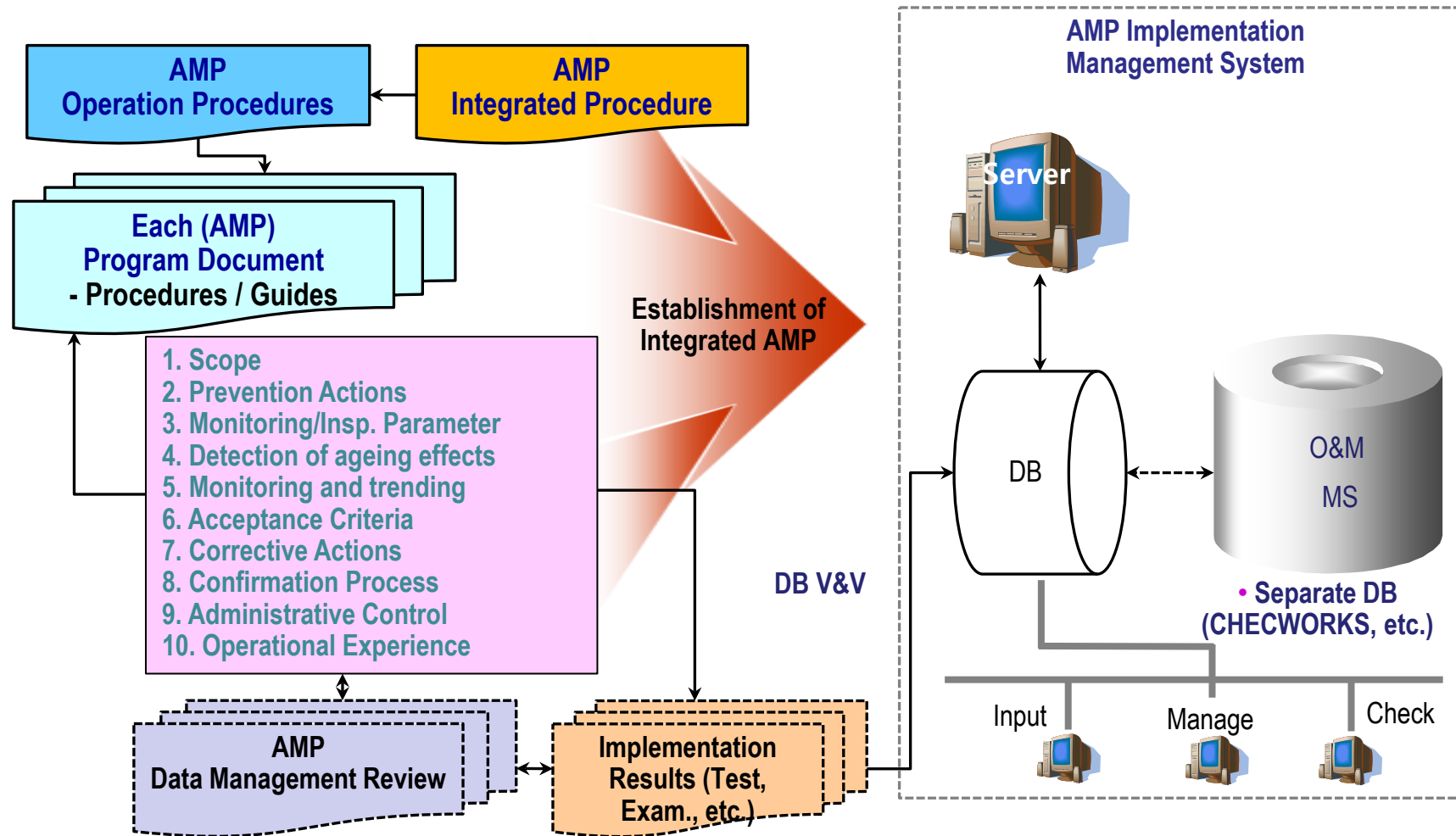


- Under this framework, **the aging management has become a living system** not only in the NPPs under continued operation but also in long-term operation NPPs.

Ageing Management for Long-term Operation

- **Post-Fukushima action for long-term operation of NPPs**
 - In accordance with the administrative order issued by the regulatory body, **the integrated AMP has been established by KHNP (Korean Utility) and implemented since 2016.**
 - **All operating NPPs have their own plant-specific AMP procedures.**
 - **Each plant has an integrated procedure for AMP and about 30~40 plant-specific operation procedures for individual AMPs.**
 - **The IT-based system called ‘AMP Implementation Management System’ has been developed and used since 2019.**
 - **The Korea regulatory body approved the integrated AMP and inspects the implementation status and results during every periodic inspection.**

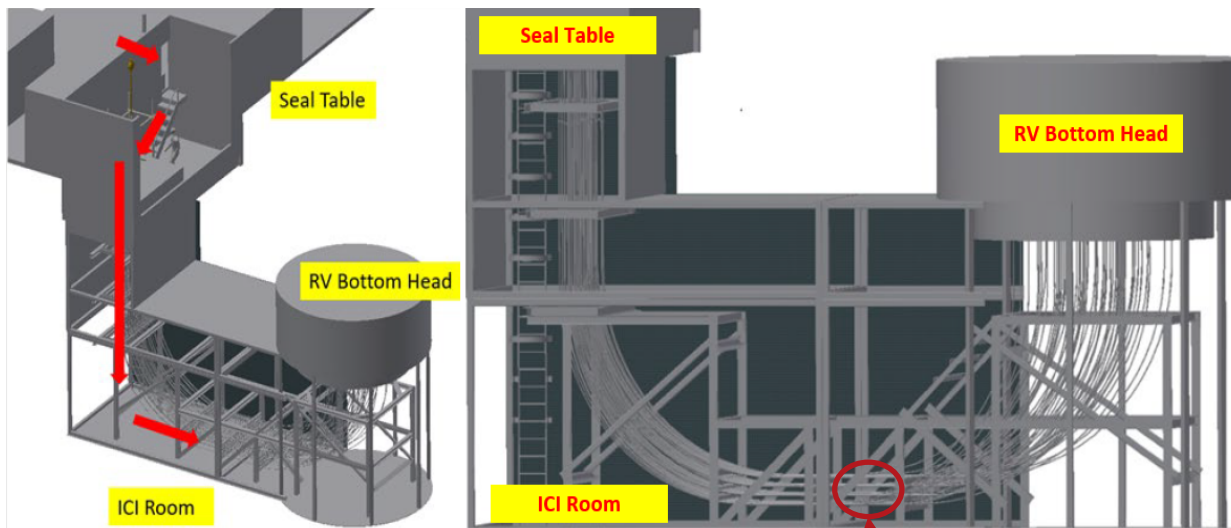
AMP Implementation Management System (by KHNP)



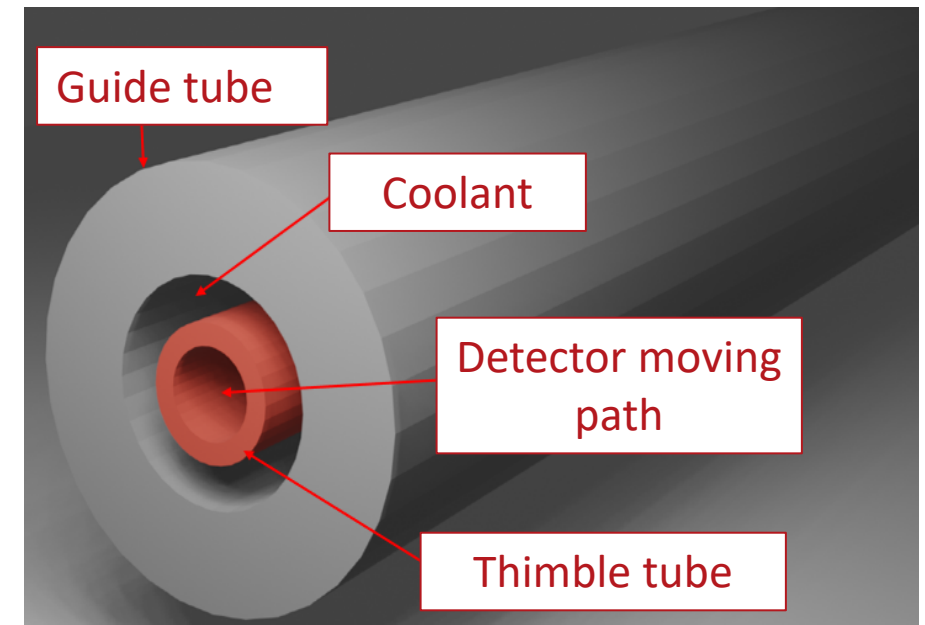
Recent Aging Issues - (1) Leakage in ICI guide tubes

- Leakage event overview

- At 3 NPPs in operation for more than 30 years, leakages have been found during their planned overhauls.
- Leaks were confirmed in the ICI tubes, and they were detected in the form of boric acid precipitation.



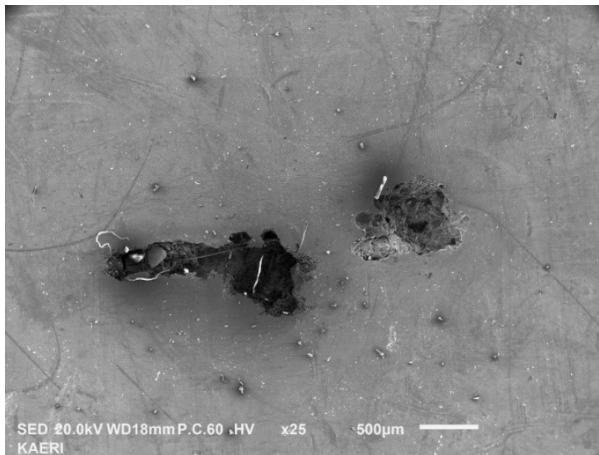
Leakage Found



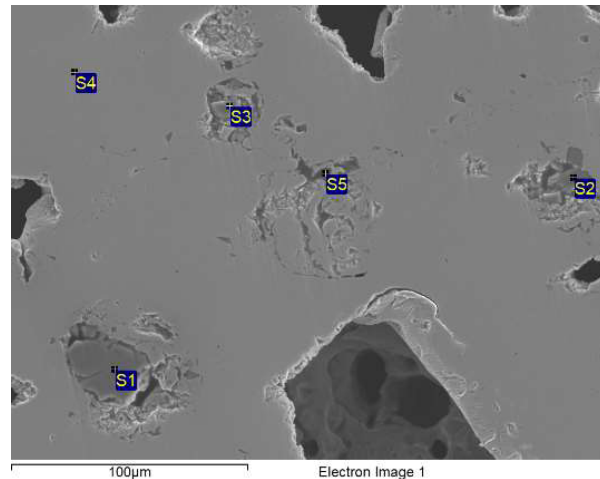
Recent Aging Issues - (1) Leakage in ICI guide tubes

● Root cause analysis results

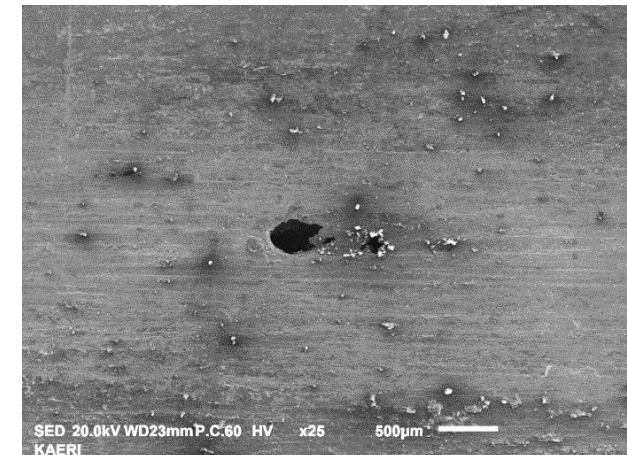
- Use of lubricants with high chlorine content in the past ⇒ **Concentration of chloride ions** due to stagnation of high temperature reactor coolant ⇒ Corrosive environment
 - **Non-metallic inclusions** such as SiC, which induced during the manufacturing process
- ⇒ **Pitting corrosion** due to corrosive water chemistry and non-metallic inclusions



OD Surface



Microstructure around the defect



ID Surface

Recent Aging Issues - (1) Leakage in ICI guide tubes

- **Corrective actions**

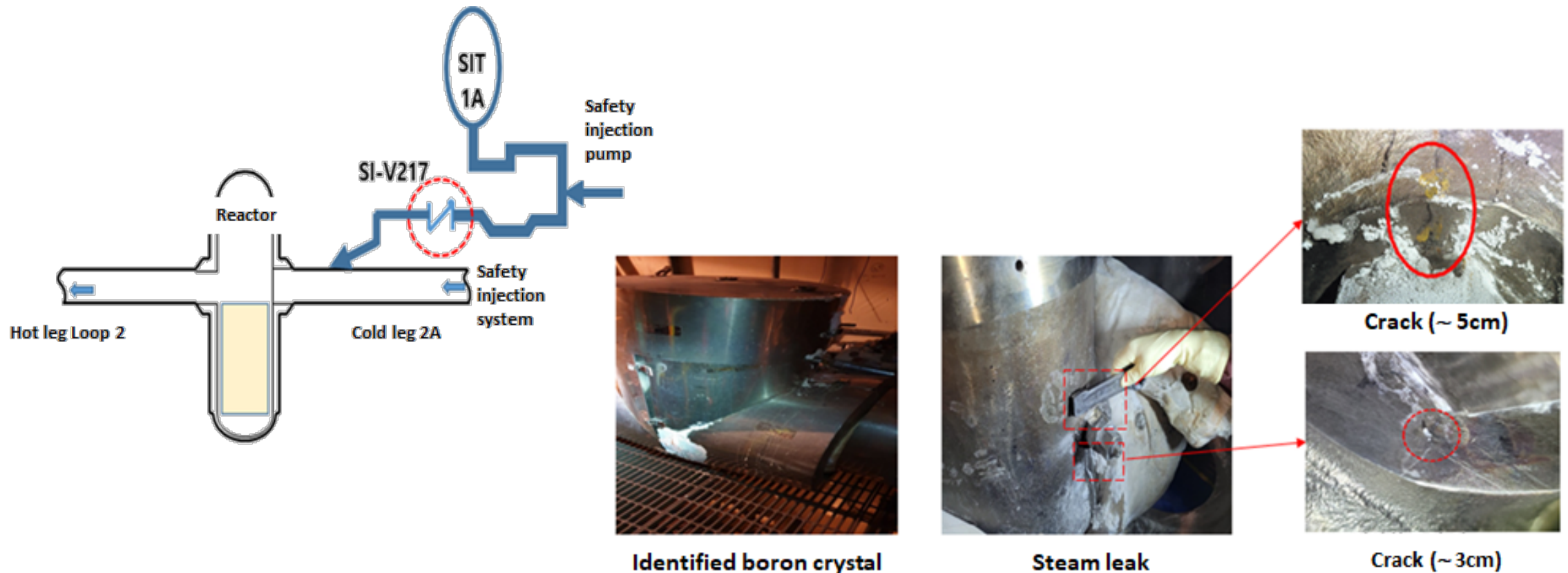
- **Chemical analyses** at all NPPs
- Depending on the results of the chemical analysis, if necessary, **reduction of impurity concentration** through gravity drainage
- For some cases, enhanced cleaning to remove residual deposits
- **Direct visual inspection** during every refueling outage
- Consideration of tube replacement

Existing AMP	Improved AMP
ASME Section XI Inservice Inspection	ASME Section XI Inservice Inspection
No effective inspection for ICI guide tubes	Effective BAC (Boric Acid Corrosion) program
None	Water Chemistry

Recent Aging Issues – (2) Leakage from Swing Check Valve Hinge

- Leakage event overview

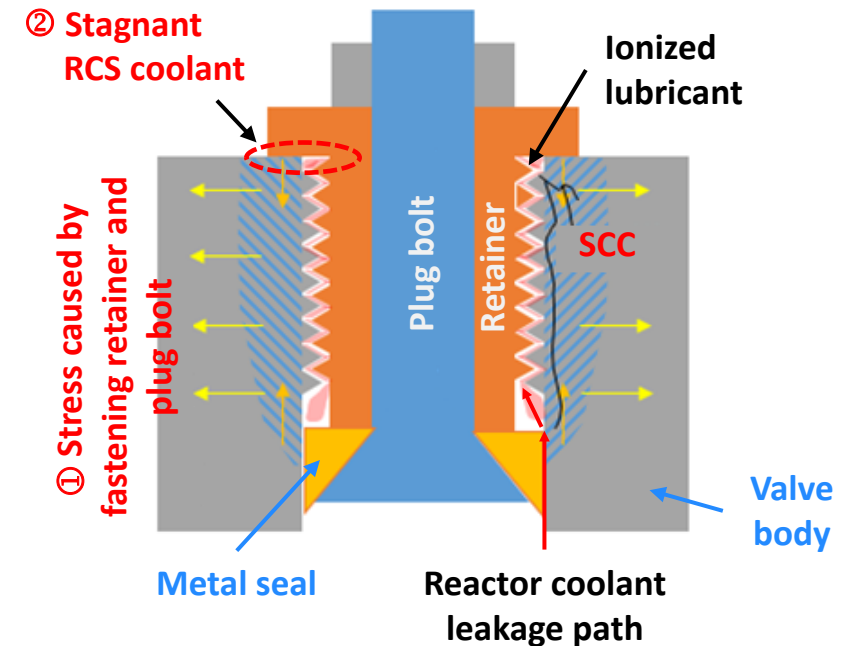
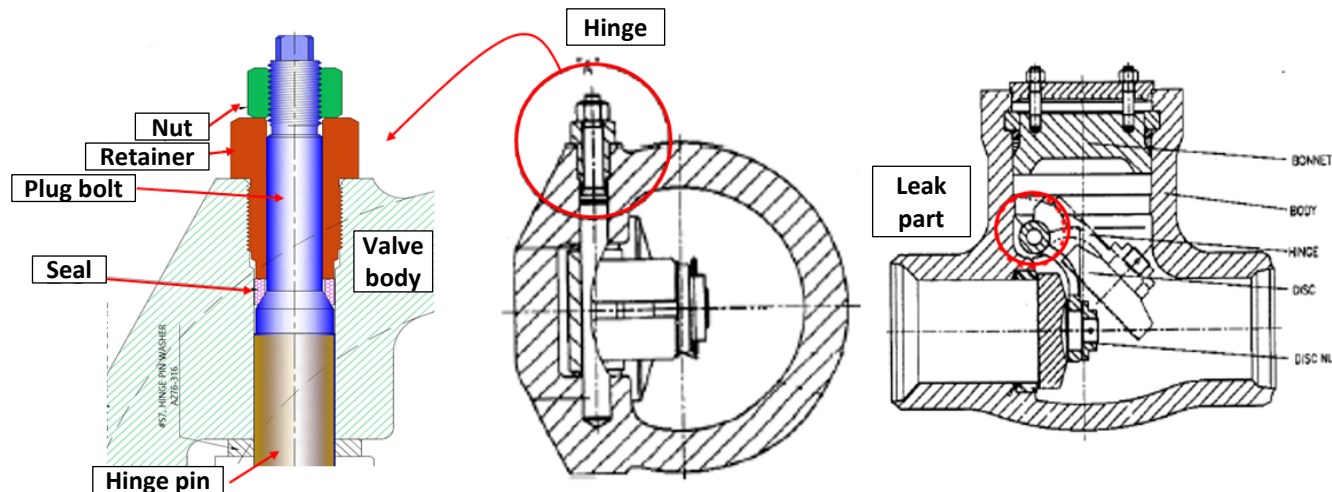
- In Jun. 2023, a steam leak was identified from the hinge part of the SI (Safety Injection) line swing check valve of a nuclear power plant that had been in operation for more than 22 years.



Recent Aging Issues – (2) Leakage from Swing Check Valve Hinge

● Root cause analysis results

- Corrosive environment due to **ionized lubricant** and **stagnant reactor coolant** between valve body and retainer
 - No specific torque value in the maintenance procedure ⇒ Excessive torque ⇒ **High stress** caused by fastening retainer and plug bolt
- ⇒ **TGSCC (Trans-Granular Stress Corrosion Cracking)** in the CASS material valve body, which caused by (1) stress and (2) corrosive environment



Recent Aging Issues – (2) Leakage from Swing Check Valve Hinge

- **Corrective actions**
 - Elimination of blind spots through **design improvement**, etc.
 - **Visual inspection** (VT-1) of the retainer-type swing check valve of similar structure using a high-resolution endoscope (borescope) camera
 - No unusual findings in 3 NPPs. For other NPPs, visual inspection in the same manner during each planned overhaul
 - **Shortened monitoring cycle** for containment air radiation, containment building sump water levels, etc.

Concluding Remarks

- **Lessons learned from recent aging issues**
 - Aging management **should be a living program** regardless of operating reactor years.
 - **Proactive measures** should be taken **to eliminate blind spots** such as coolant stagnation.
 - Domestic and overseas **operating experiences should be reflected** into the aging management programs in a timely manner.
- **How to meet the moment?**
 - For more efficient and effective aging management of NPPs, efforts should be made to **utilize today's innovative and cutting-edge technologies** such as big data and AI.
 - Proactive adoption of innovative technologies for aging management will require a **transformation in the mindset** of both operators and regulators, as well as **a faster process to demonstrate and verify the safety of technologies** that differ from existing approaches.