International Conference on Small Modular Reactors and their applications, 21-25 October 2024, Vienna, Austria

Maintenance strategy for i-SMR

24. Oct., 2024

KHNP Central Research Institute
SMR NSSS Design Group

HYUN-SUK NAM

KOREA HYDRO & NUCLEAR POWER CO.,LTD

I. Background - i-SMR Development Status

Target Goal : SDA approval by 2028, FOAK operation in 2031

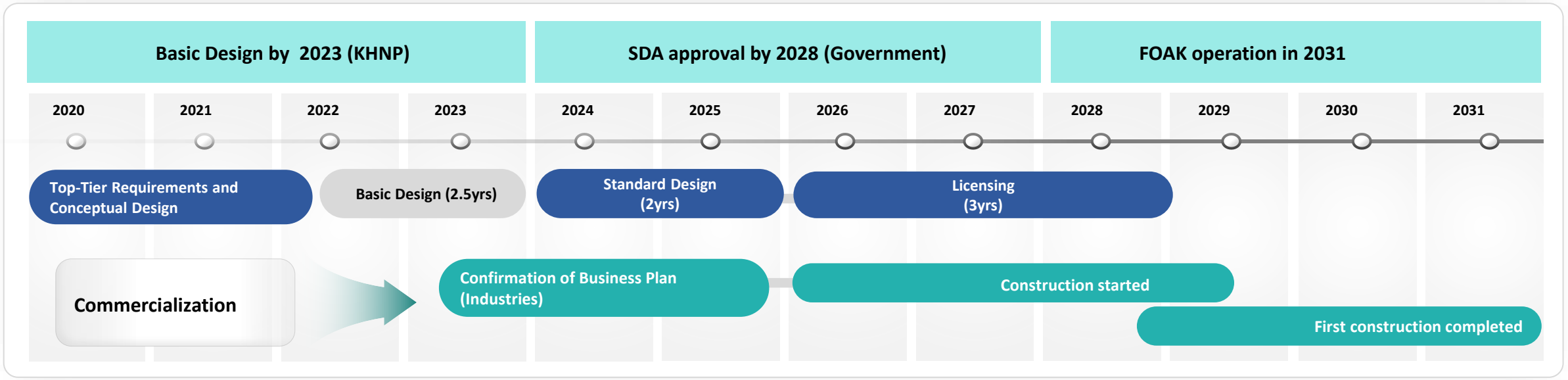
Preliminary Design led by KHNP

- KHNP project (KAERI, KEPCO E&C, KNF, Doosan, Academic)
  - Period : '21 ~ '23 — 3years
  - Budget : $40 Million

National R&D Projects Supported by the Government

- MSIT * /MOTIE * project
  - Period : '23 ~ '28 — 6years
  - Budget : $300 Million

* MSIT : Ministry of Science and ICT / MOTIE : Ministry of Trade, Industry and Energy



Design Requirement (1/2)

General

- PWR (Pressurized Water Reactor)
- Power Output : 170 MWe/Module
- Site : Operational both along the coast and inland
- Design Life : 80 years

Safety

- CDF (Core Damage Frequency) : 1.0e-9/MY
- LERF (Large Early Release Frequency) : 1.0e-10/MY
- SBO (Station Black Out) response time : ≥ 72 hours
- Fuel thermal margin: ≥ 15%
- EPZ (Emergency Planning Zone) : with in site boundary
- Completely passive core/containment cooling

Design Requirement (2/2)

Plant Performance

- Plant availability factor : ≥ 95% for 24 months fuel cycle
- Unplanned trip : ≤ 0.2 times/MY (Less than 3 days/year)
- Planned trip : ≤ 24 days/MY
- Refueling cycle : ≥ 24 months

Constructability

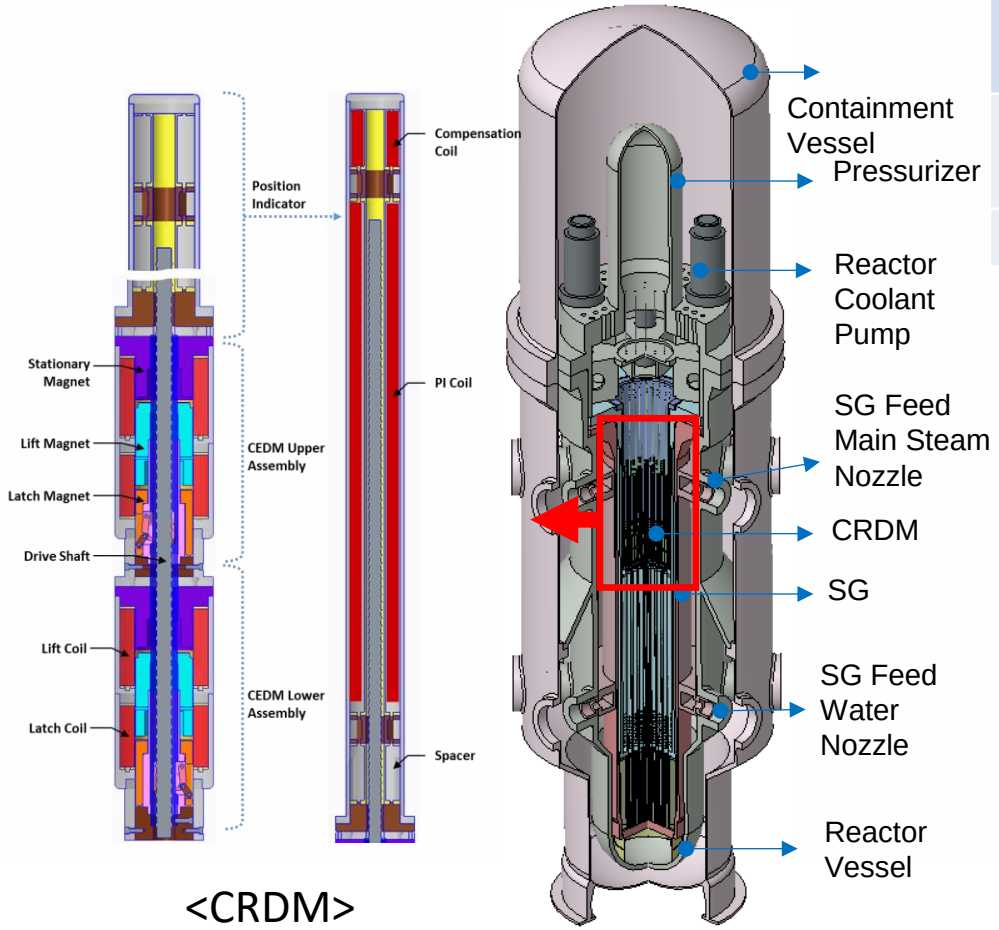
- Module design for factory manufacturing and land transportation
- Modulization of buildings
- Construction time : First Rx for 24 months / Plant for 42 months (CP ~ OL)

Design Requirement (2/2)

Geometry and Major Components

- Containment Vessel
- Integrated Reactor Vessel
- In-Vessel Control Rod Drive Mechanism
  - Mounted on the Reactor Internals in the RV
  - Elimination of Control Element Assembly ejection accident
- Pressurizer
- Reactor Coolant Pump (4 pumps)
  - Vertically installed, canned motor pumps
  - A canned motor pump does not need pump seals
- Steam Generator
  - Helical once-through type
  - Provide the maximum heat transfer area in limited space

Component		No.
Containment Vessel (CV)		1
Reactor Vessel (RV)		1
Pressurizer (PZR)		1
Reactor Coolant Pump (RCP)		4
Steam Generator (SG) Helical Type		1
SG Nozzle	Feed Water	8
	Main Steam	8
CRDM		49



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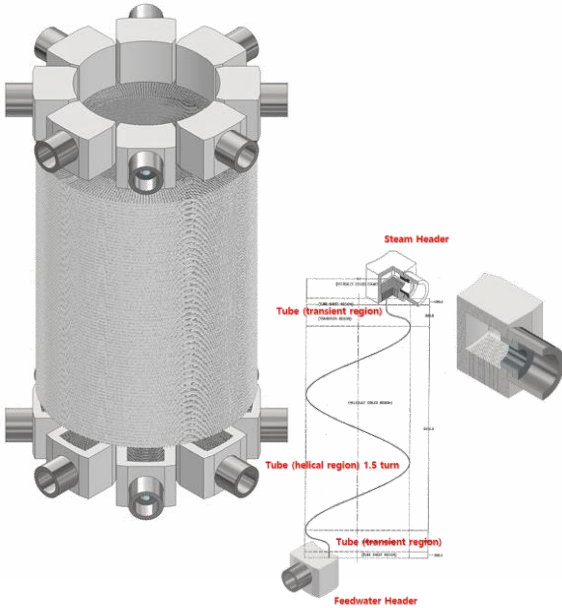
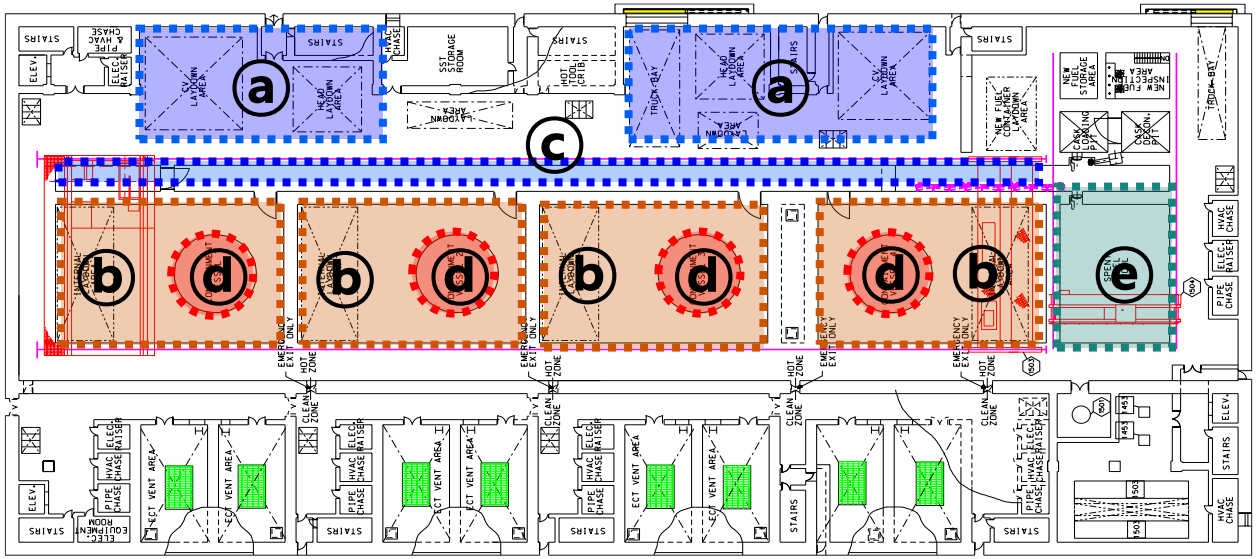
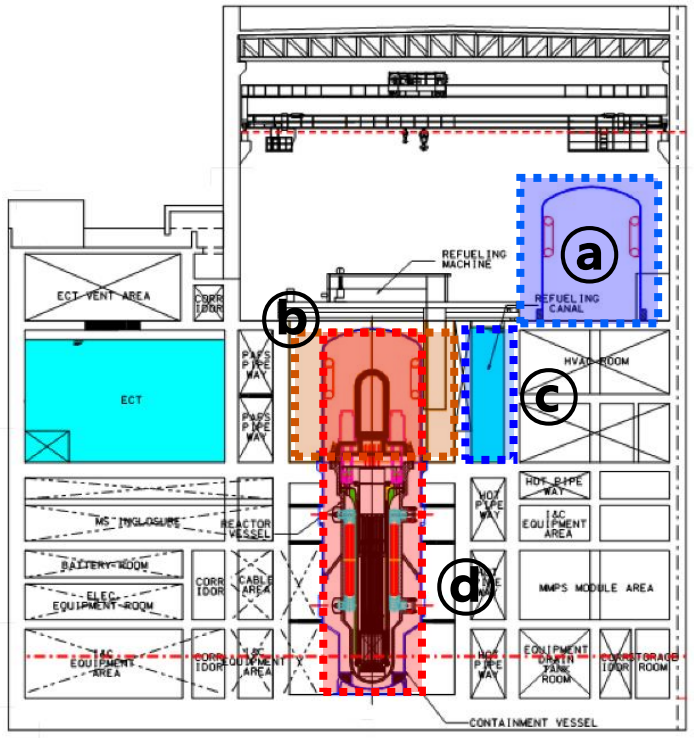


<SG>

Maintenance strategies for i-SMR

- The i-SMR is being designed to meet the target component/inspection requirements of code & standards
- Also, simple and convenient maintenance procedures were considered when designing the i-SMR.
- For maintenance efficiency, each module can be serviced without moving from the refueling pool. This concept allows for the removal of the upper head's stud bolts in an atmospheric environment.





a : Laydown area

c : Refueling canal
① Normal operating condition : Under Water
② Refueling Condition : Under Water

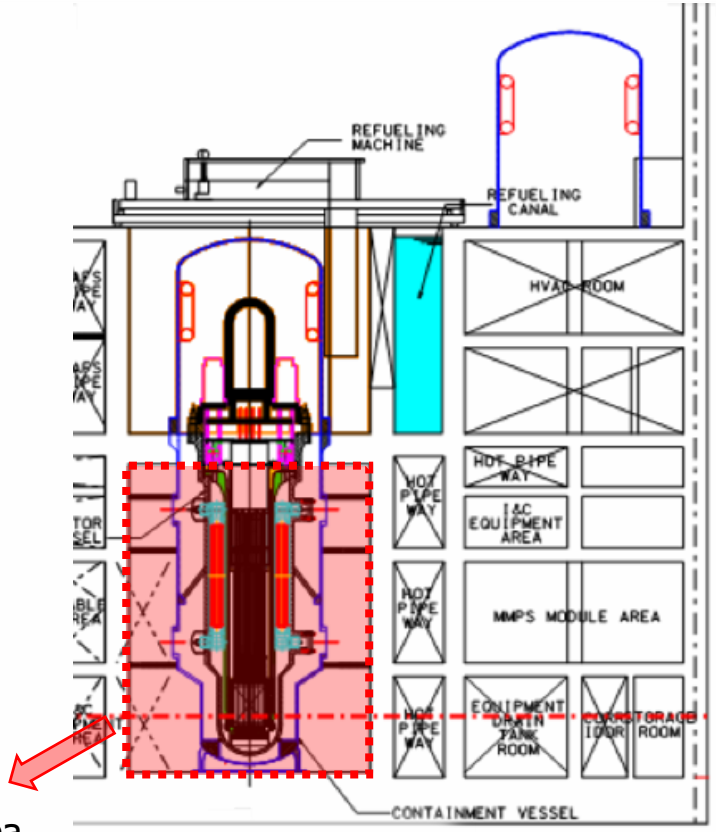
b : Refueling pool
① Normal operating condition : Dry
② Refueling Condition : Under Water

d : Reactor

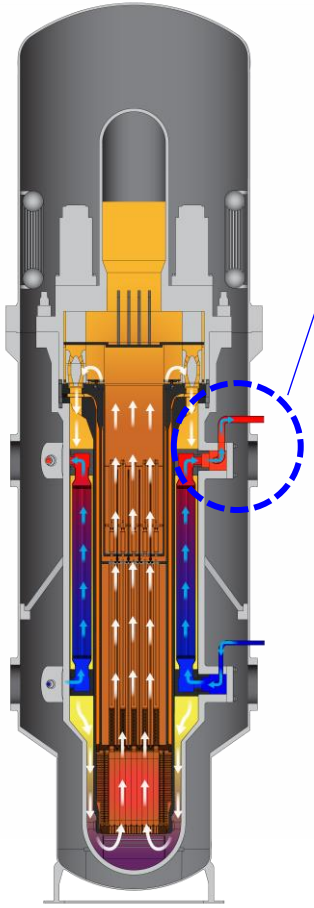
e : Spent fuel pool

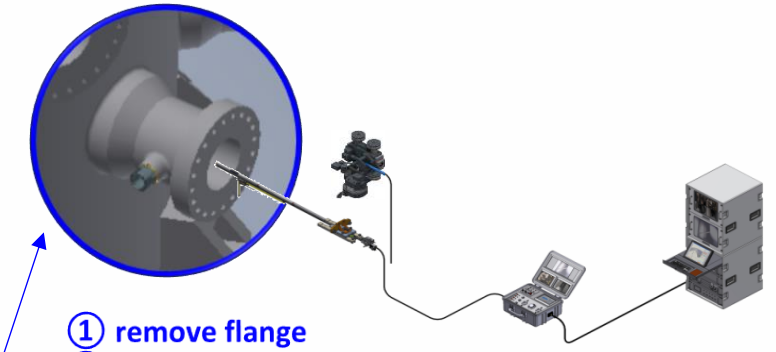
Maintenance strategies for i-SMR

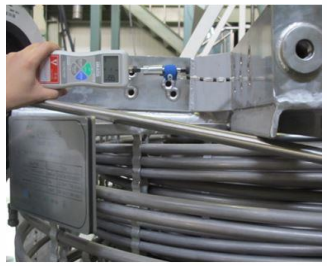
- The space below the Refueling pool can be utilized for RV/CV inspection
- In this space, the steam generator tubes are inspected by inserting a probe into each tube.
- When developing the SMART100, the feasibility of inserting an ECT probe into a small curvature helical SG tube was validated.

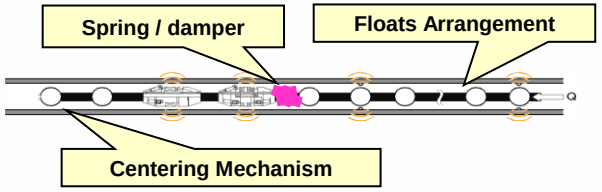


Maintenance area
① Normal operating condition : Dry
② Refueling Condition : Dry







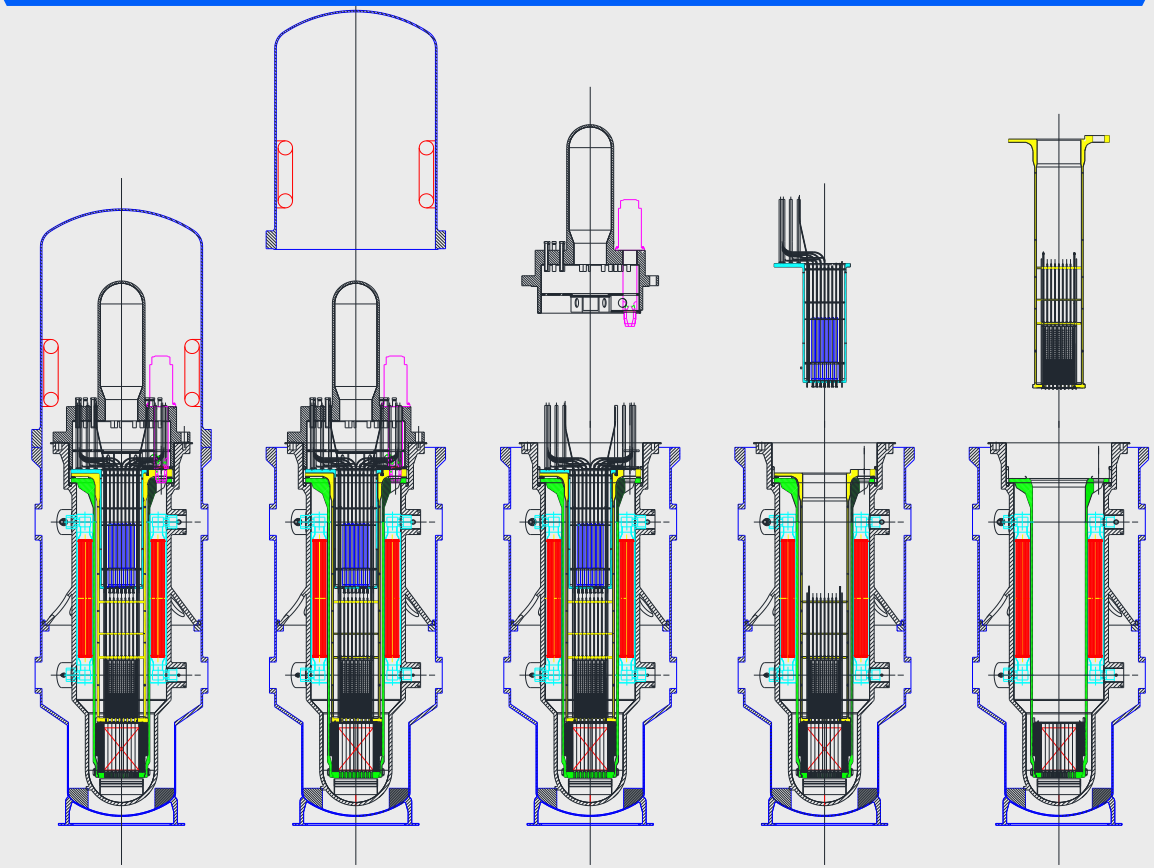


ECT equipment

SG ECT Concept

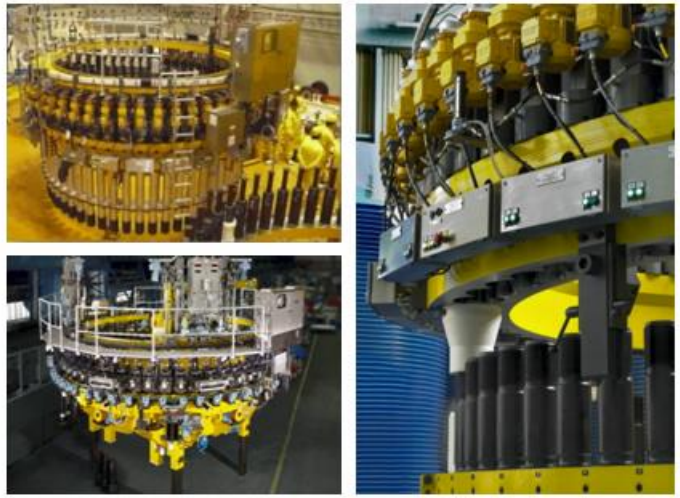
Maintenance process for RV/CV main component in the i-SMR

Disassembly & Assembly process for RV/CV



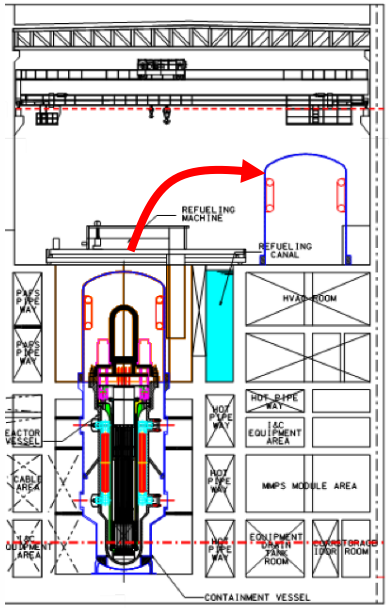
No.	Maintenance item
①	**CV head disassembly & inspection**
①-ⓐ	Disassembly of CV stud bolts(60ea)
①-ⓑ	Disassembly of CV head
①-ⓒ	Non destructive test(NDT) of CV weld
①-ⓓ	PCCS inspection
②	**RCH disassembly & maintenance**
②-ⓐ	Removal of CEDM/ICI/I&C cables and seals
②-ⓑ	Removal of RV stud bolts(36ea)
②-ⓒ	Removal of RCH & increasing of CV pool level
②-ⓓ	RCP maintenance
②-ⓔ	Inspection for CEDM/ICI penetration
②-ⓕ	RCH welds inspection
③	**RVI (IBA→UGS →CSB) remove & maintenance**
③-ⓐ	IBA integrated IV-CEDM
③-ⓑ	RVI inspection
④	**Transfer the fuel assembly(69 ea) to SFP**
⑤	**NDT inspection for main component**
⑤-ⓐ	RV lower interior weld inspection
⑤-ⓑ	RV lower exterior weld inspection
⑤-ⓒ	CV lower weld inspection
⑤-ⓓ	ECT inspection for SG tube

Maintenance process for RV/CV main component in the i-SMR - ① CV Head disassembly & Inspection



Multiple stud Tensioner

① - ⓐ



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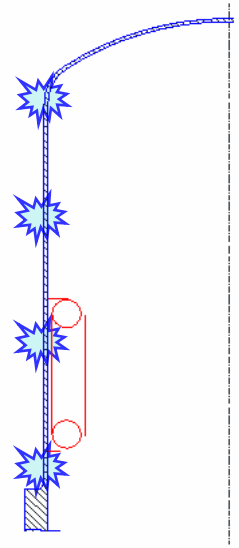
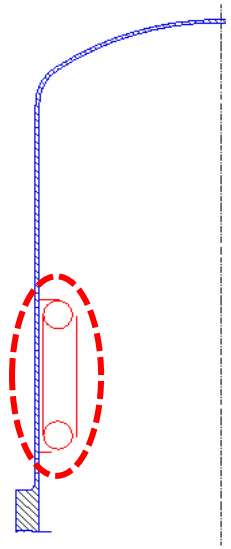


: Inspection point

① - ⓒ

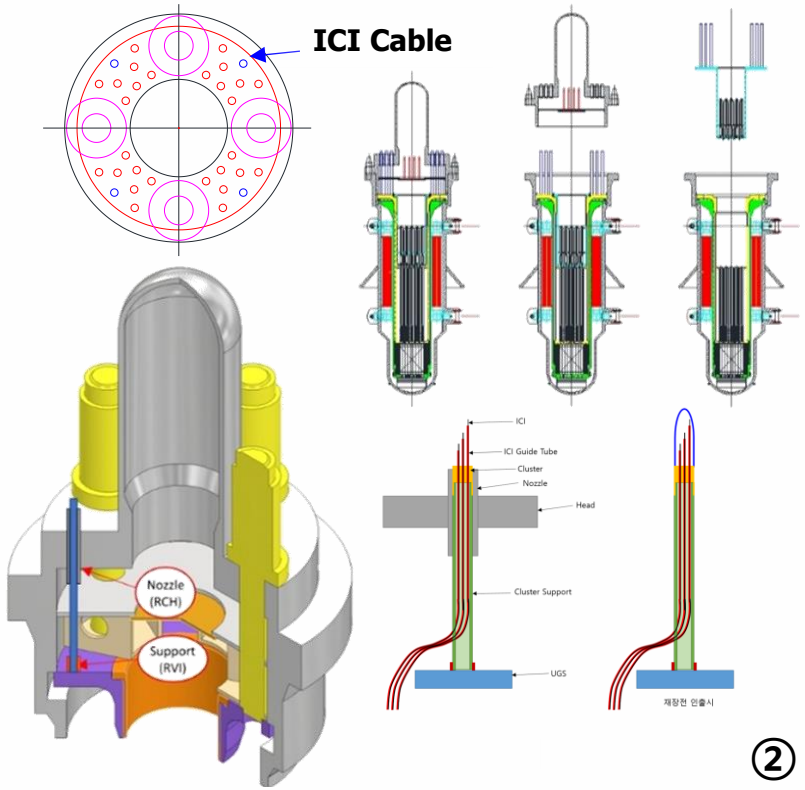


PCCS inspection

① - ⓓ

No.	Maintenance item	process details and maintenance tools
①	CV head disassembly & inspection	· CV head is maintained at service area
①-ⓐ	Disassembly of CV stud bolts(60ea)	· By using Multiple Stud Tensioner, multiple bolts are removed at the same time
①-ⓑ	Disassembly of CV head	· By using reactor building crane, CV head is transferred to Laydown area
①-ⓒ	Non destructive test(NDT) of CV weld	· CV upper head weld inspection is performed at laydown area
①-ⓓ	PCCS inspection	· PCCS inspection is performed at laydown area

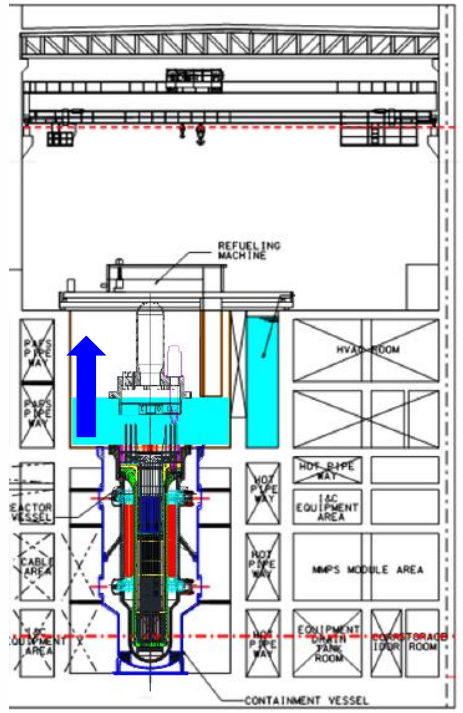
Maintenance process for RV/CV main component in the i-SMR - ② RCH maintenance



② - ⓐ

CEDM/ICI Cable removal & lifting process

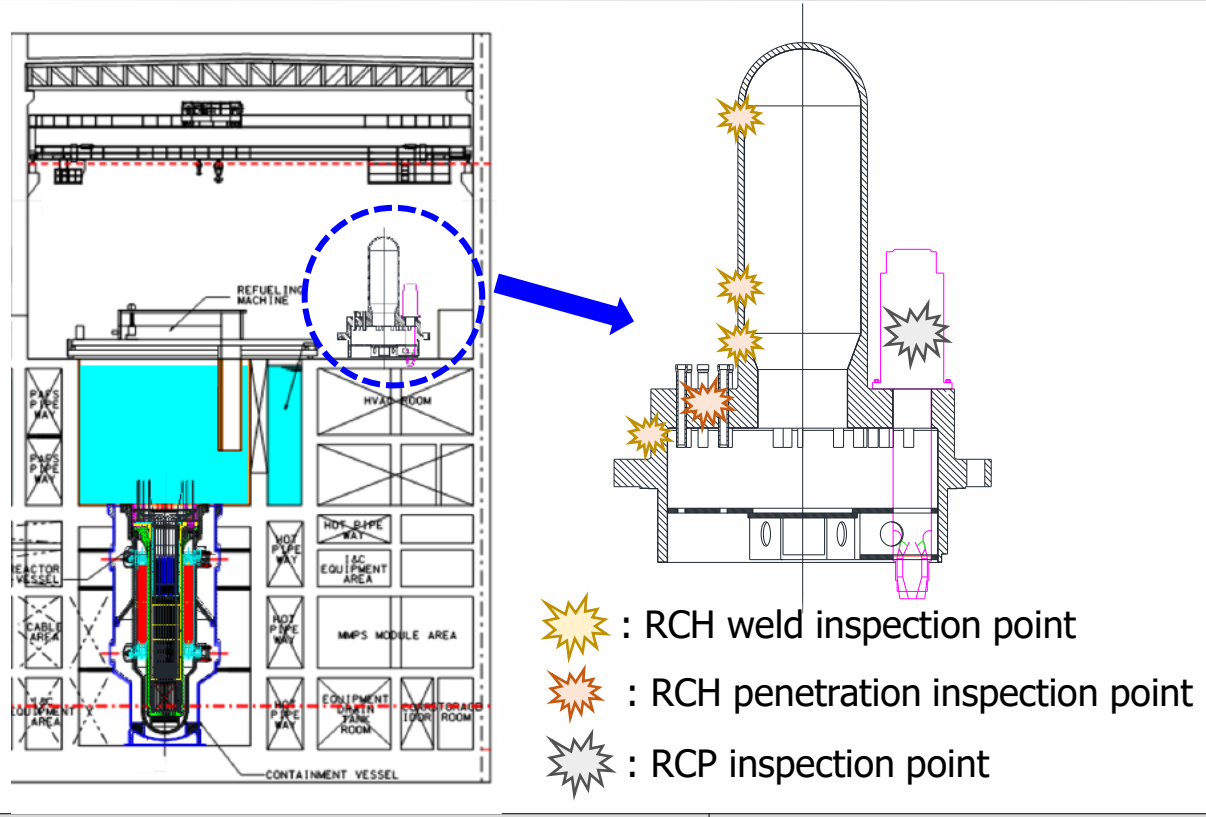
- Disconnect the cable at CV
- Disassembly the seal device
- Install the bullet nose assembly
- Lift the reactor closure head
- disassemble the bullet nose
- Install ICI withdrawal tool
- Withdrawal of ICI
- Disposal of ICI



② - ⓒ

No.	Maintenance item	process details and maintenance tools
②	RCH maintenance	(a) Remove of CEDM/ICI penetration seal, (b) Disassembly of RCH, and Increasing of level of CV pool (at the same time)
②-ⓐ	Removal of CEDM/ICI cables and seals	CEDM/ICI cables are dismantled.
②-ⓑ	Removal of RV stud bolts(36ea)	After CEDM/ICI cables removal, multiple bolts are removed as same with CV stud bolts,
②-ⓒ	Removal of RCH & increasing of CV pool level	· By using reactor building crane, RCH is transferred to RCH Laydown area and CV pool water level is increased at the same time·

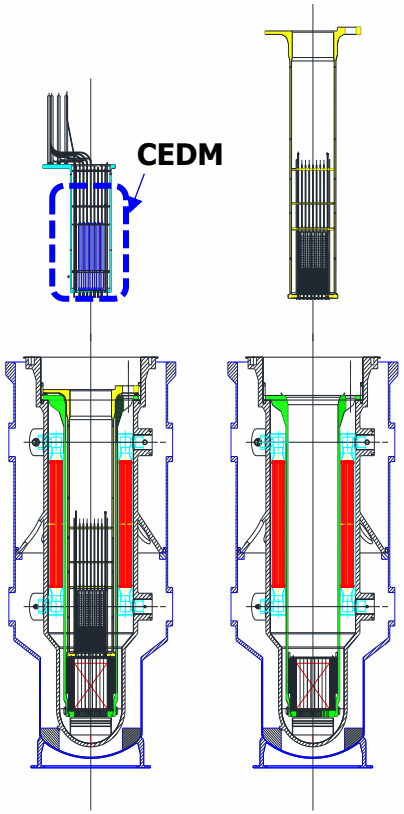
Maintenance process for RV/CV main component in the i-SMR - ② RCH maintenance

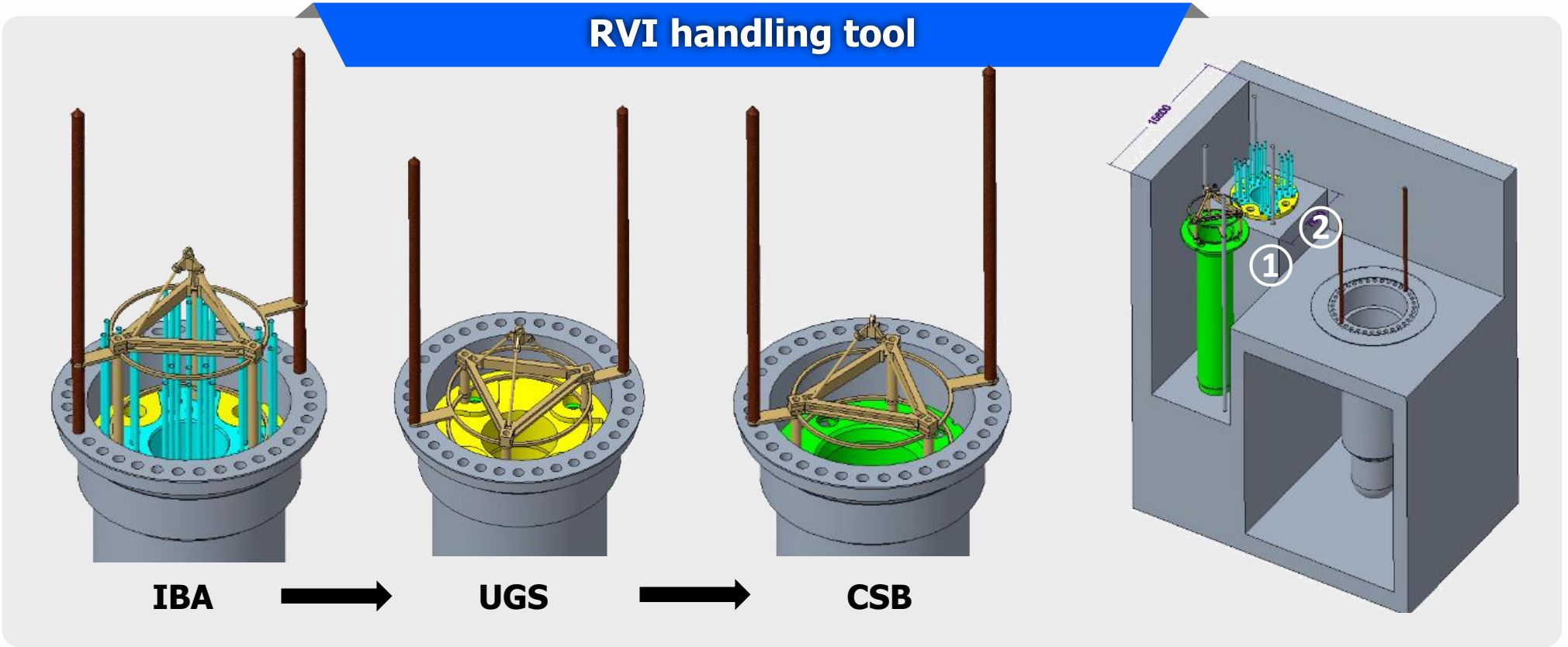


UT testing tool (example)

No.	Maintenance item	process details and maintenance tools
②	RCH maintenance	(a) Remove of CEDM/ICI penetration seal, (b) Disassembly of RCH, and Increasing of level of CV pool (at the same time)
②-ⓓ	RCP maintenance	· After RCH moves to laydown area, RCP is maintained at laydown area
②-ⓔ	Inspection for CEDM/ICI penetration	· UT, ECT, VT inspections for penetration are performed at laydown area
②-ⓕ	RCH welds inspection	· RCH welds inspection is performed at laydown area

Maintenance process for RV/CV main component in the i-SMR - ③ RVI Remove & maintenance

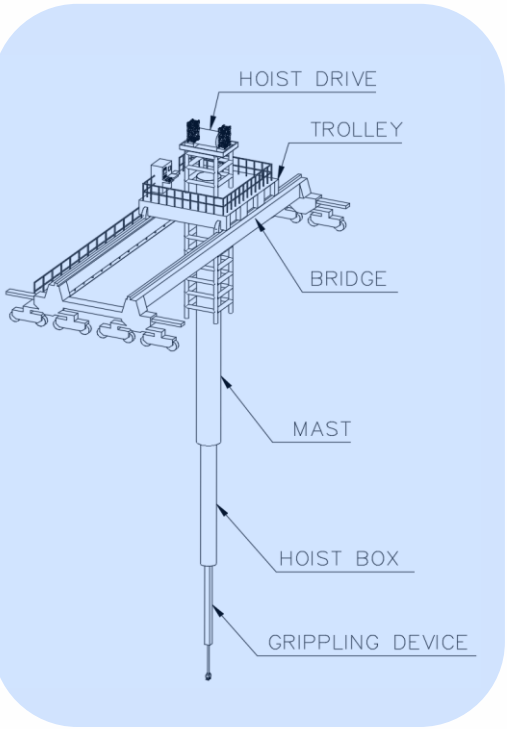




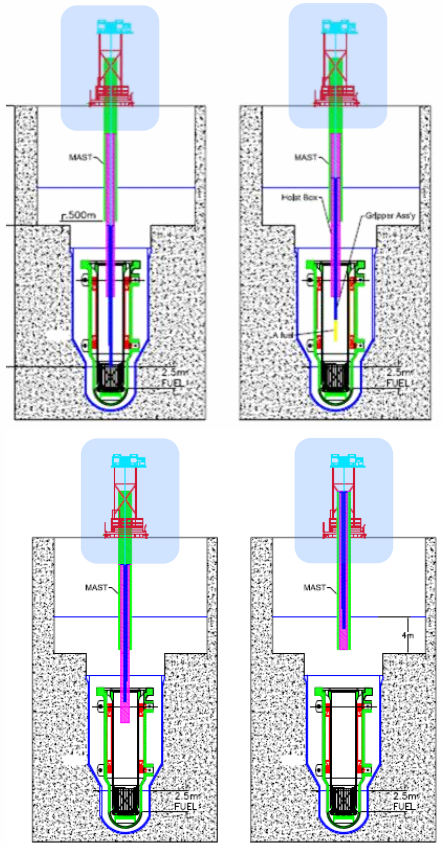
No.	Maintenance item	process details and maintenance tools
③	RVI (IBA→UGS →CSB) removal & maintenance	· The RVIs are removed in the order IBA-UGS-CSB and stored in the refueling pool
③-ⓐ	IBA integrated IV-CEDM	· IV-CEDM (IBA integrated) inspection
③-ⓑ	RVI inspection	· Visual inspection (VT-3)

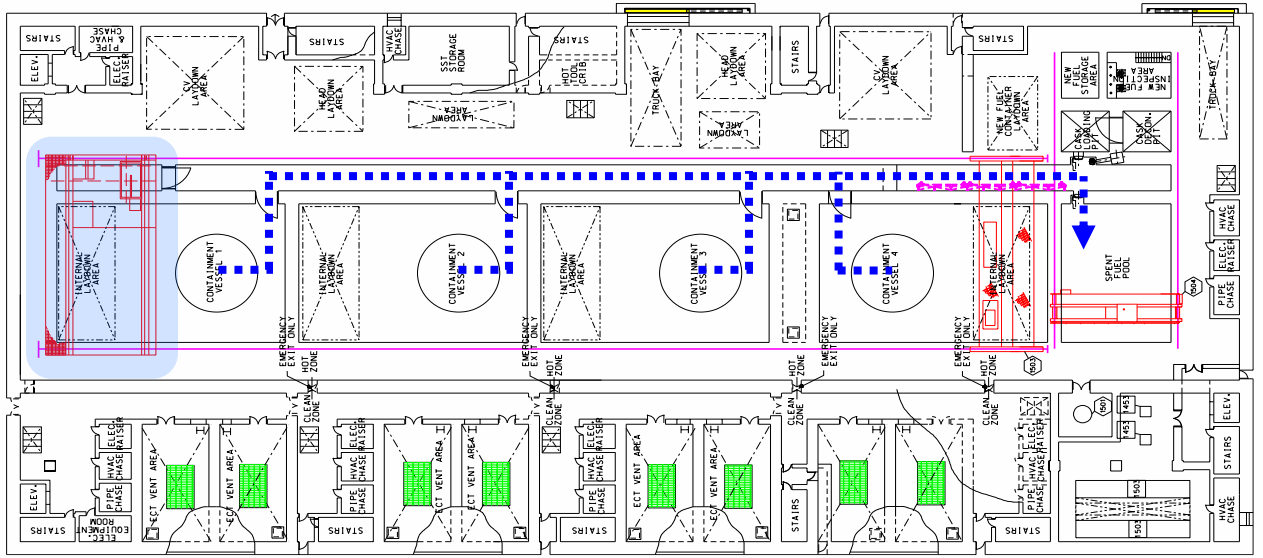
Maintenance process for RV/CV main component in the i-SMR - ④ Transfer the fuel assembly to SFP

Refueling Process



Refueling Machine

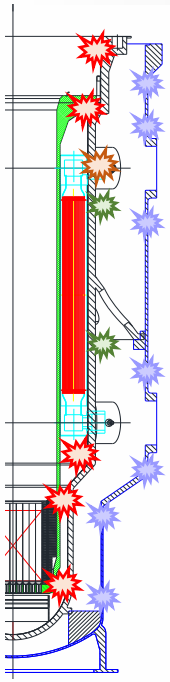




Refueling path

No.	Maintenance item	process details and maintenance tools
④	Transfer the fuel assembly(69 ea) to SFP	· **Unloading of fuel assembly**

Maintenance process for RV/CV main component in the i-SMR - ⑤ NDT inspection for main component

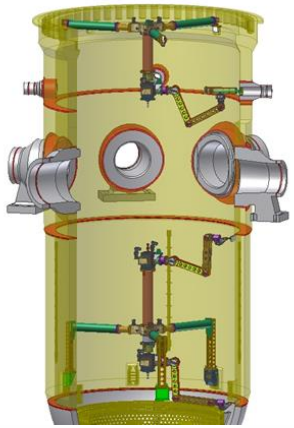


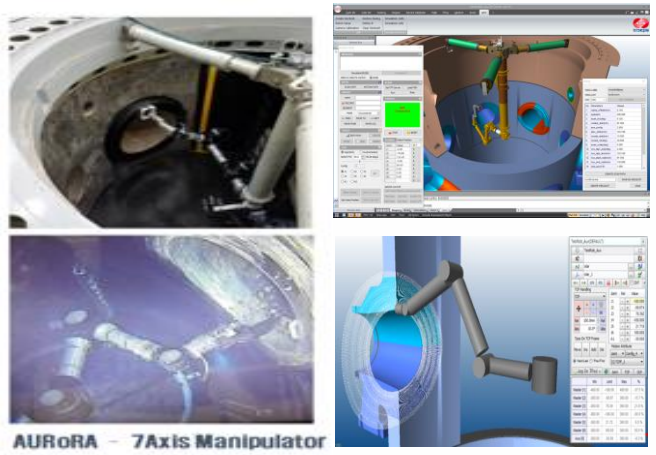
: CV Inspection point (outside)

: RV Inspection point (outside)

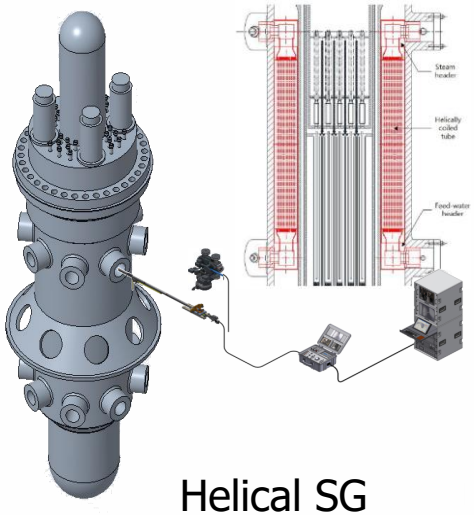
: RV Inspection point (inside)

: SG Inspection point





Vessel Inside & outside

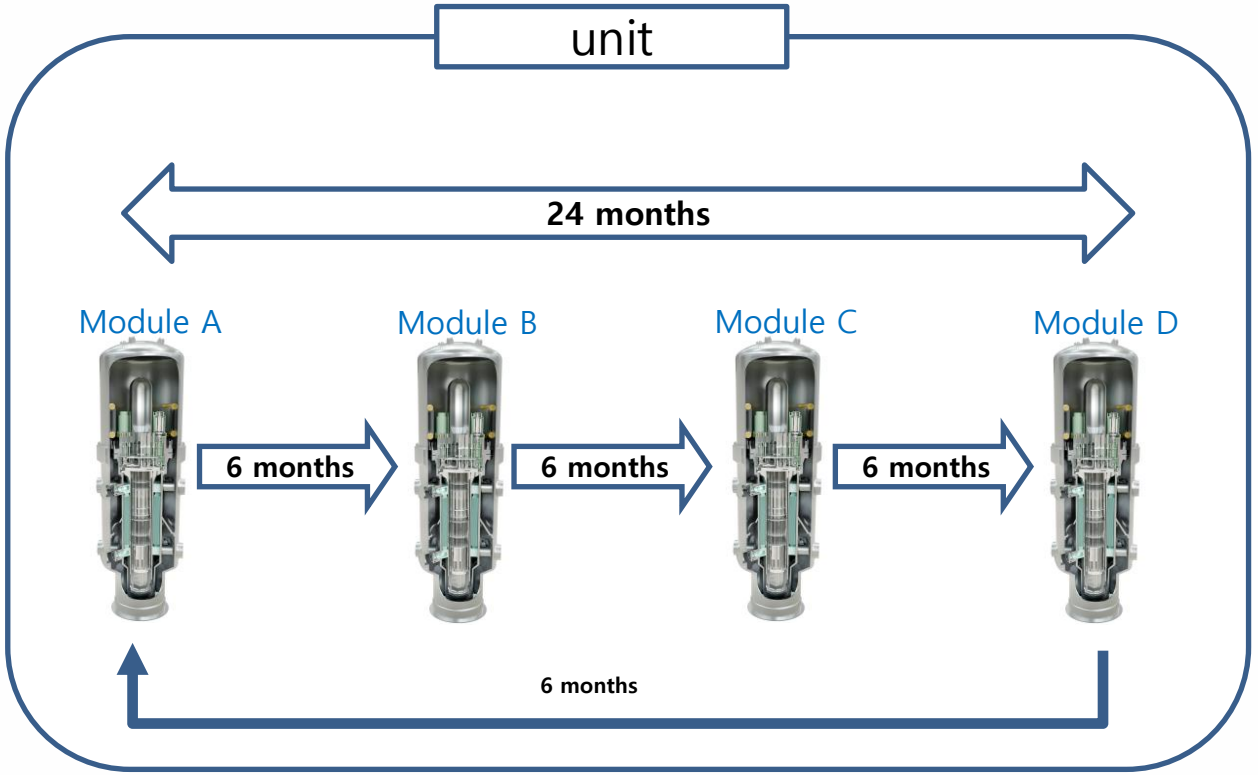


Helical SG

Inspection tool (example)

No.	Maintenance item	process details and maintenance tools
⑤	**NDT inspection for main component**	**· UT inspection for RV/CV welds**
⑤-ⓐ	RV lower interior weld inspection	· RV welds, which have no interference of SG, UT inspection is performed at the RV interior
⑤-ⓑ	RV lower exterior weld inspection	· RV welds, which have interference of SG, · By using UT drone, RV welds inspection is performed at RV exterior (area between CV & RV)
⑤-ⓒ	CV lower weld inspection	· UT inspection of CV exterior surface
⑤-ⓓ	ECT inspection for SG tube	· By using May-way(SG upper part) for CV-RV SG

Simple maintenance procedures for incearing i-SMR availability



- i-SMR, designed based on KHNP's operation experience, has an optimized maintenance strategy
- i-SMR has developed a maintenance strategy utilizing proven technologies to overcome the limitations of integral reactors.Also, simple and convenient maintenance procedures were considered when designing the i-SMR.
- i-SMR aims to increase availability based on simple maintenance procedures.

Thank You for your listening

KHNP