



# Preliminary Study on the Repair and Transportation Methods of Spent Nuclear Fuel Assembly in KAERI



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# 01 Introduction

## » Background

- KAERI has transported the spent fuels from nuclear power plants (NPP) to the PIEF for the purpose of research and development since 1987, and the fuels currently in PIEF storage pool.
- Significant changes in social & political environment around KAERI
  - ✓ The National Assembly, local governments, and local residents are constantly raising concerns over the risk of spent fuels and radioactive wastes stored in KAERI.
  - ✓ Claim to return of SF & No additional transportation.
  - ✓ Transparent disclosure of test activities & inspections by citizen
- KAERI promised to return all spent fuels in PIEF to the Nuclear Power Plants from 2021
  - ✓ However, this can be changed according to the local public acceptance and government's decision.





# 01 Introduction

## » Introduction to KAERI-PIEF

### ■ Post Irradiation Examination Facility(PIEF) at KAERI

#### Overview

##### History

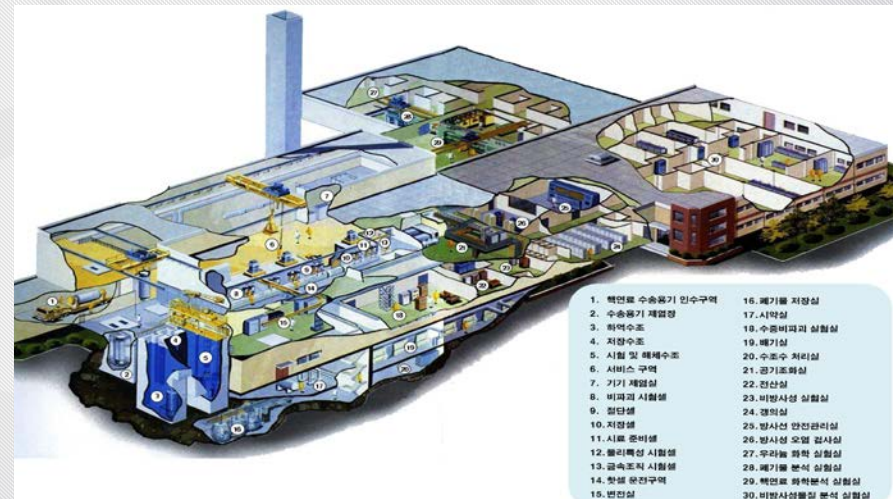
- Construction : 1981 ~ 1985
- Test Operation : 1986 ~ 1990
- Normal Operation : Since 1991
- Budget : 17 million dollars
- Total floor space : 758m<sup>2</sup> (two stories above ground and three underground levels)

##### Function

- In-core Performance and Integrity Evaluation of Nuclear Fuels
- PIEs of PWR Fuel in Pool and Hot Cells
- PIEs for Research/Development in the field of Nuclear Materials & Fuels in Domestic Companies and Foreign Institutes

##### Main Facility

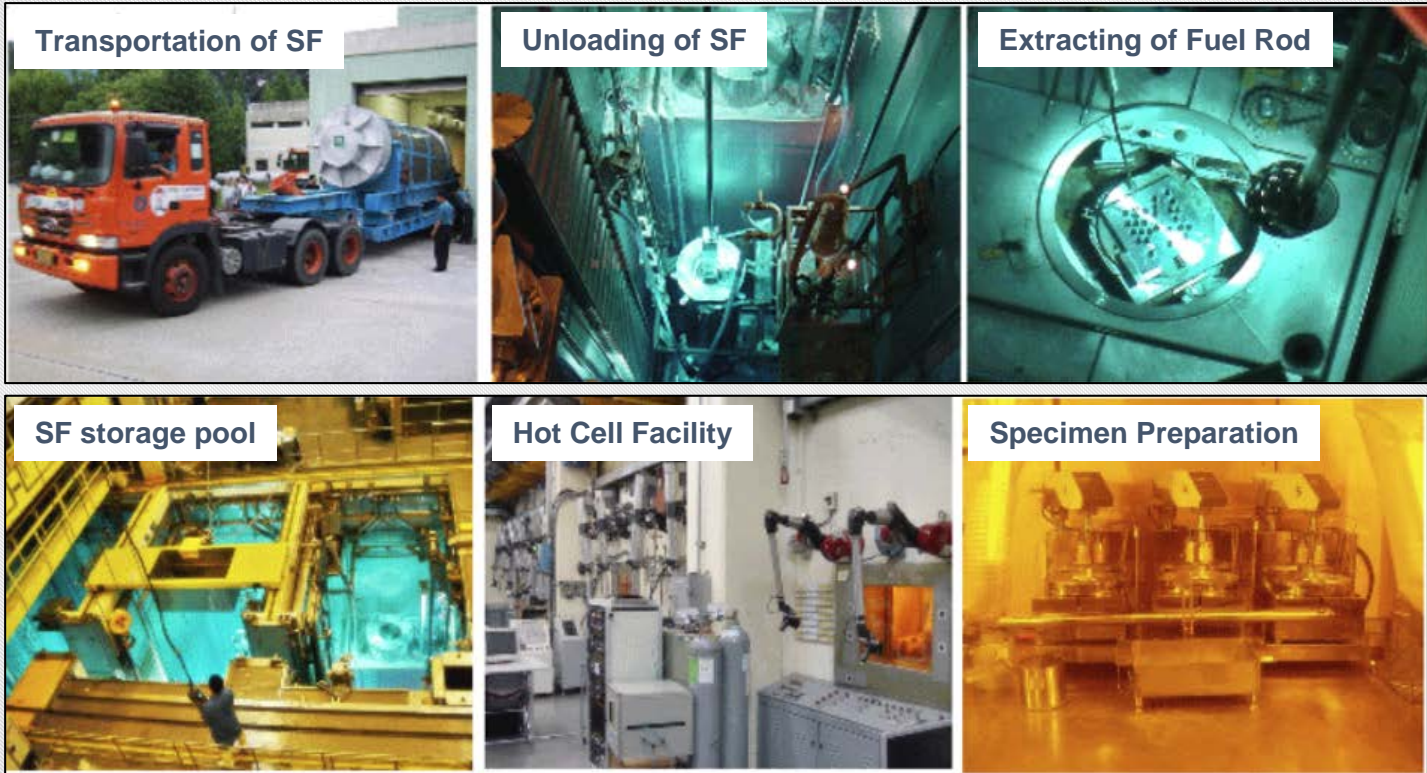
- 3 Pools : Unloading Transportation Cask, Storage of Nuclear Fuels, Pool Side Inspection and Dismantling of Fuel Assembly
- 6 Hot Cells : 4 Concrete Cells (Wall Thickness 85 cm), 2 Lead Cells (Wall Thickness 15 cm)
- Hot Laboratory : Mechanical Test of Irradiated Cladding and Irradiated Spacer Grid





# 01 Introduction

## » Introduction to KAERI-PIEF

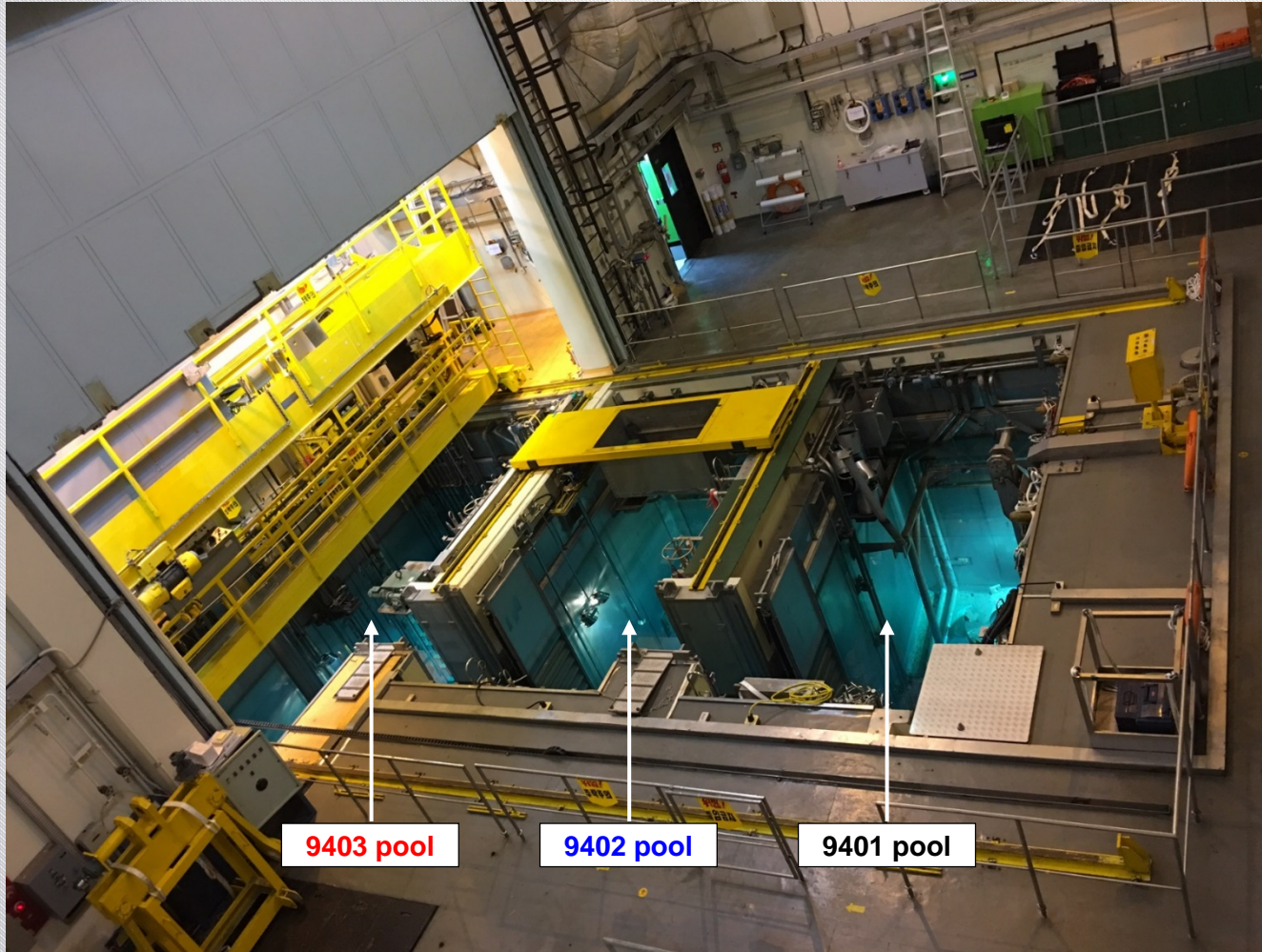


- Visual Inspection (storage pool)
- Specimen preparations, Non-destructive examinations, Dimension measurements (Hot cell)
- Mechanical tests for cladding (compressive / fatigue / creep tests), Hydrogen analysis, Delayed hydride cracking
- Microstructure / Composition analyses for fuels using SEM, EDS, EBSD, WDS (Hot lab)



## 02 Status of Spent Fuels in KAERI-PIEF

### » PIEF storage pool



- **No.1 pool (9401)**

- Cask unloading
- 6.5x3.0x15.5 (m)

- **No.2 pool (9402)**

- Storage of Spent Fuels
- 6.5x3.0x10.0 (m)

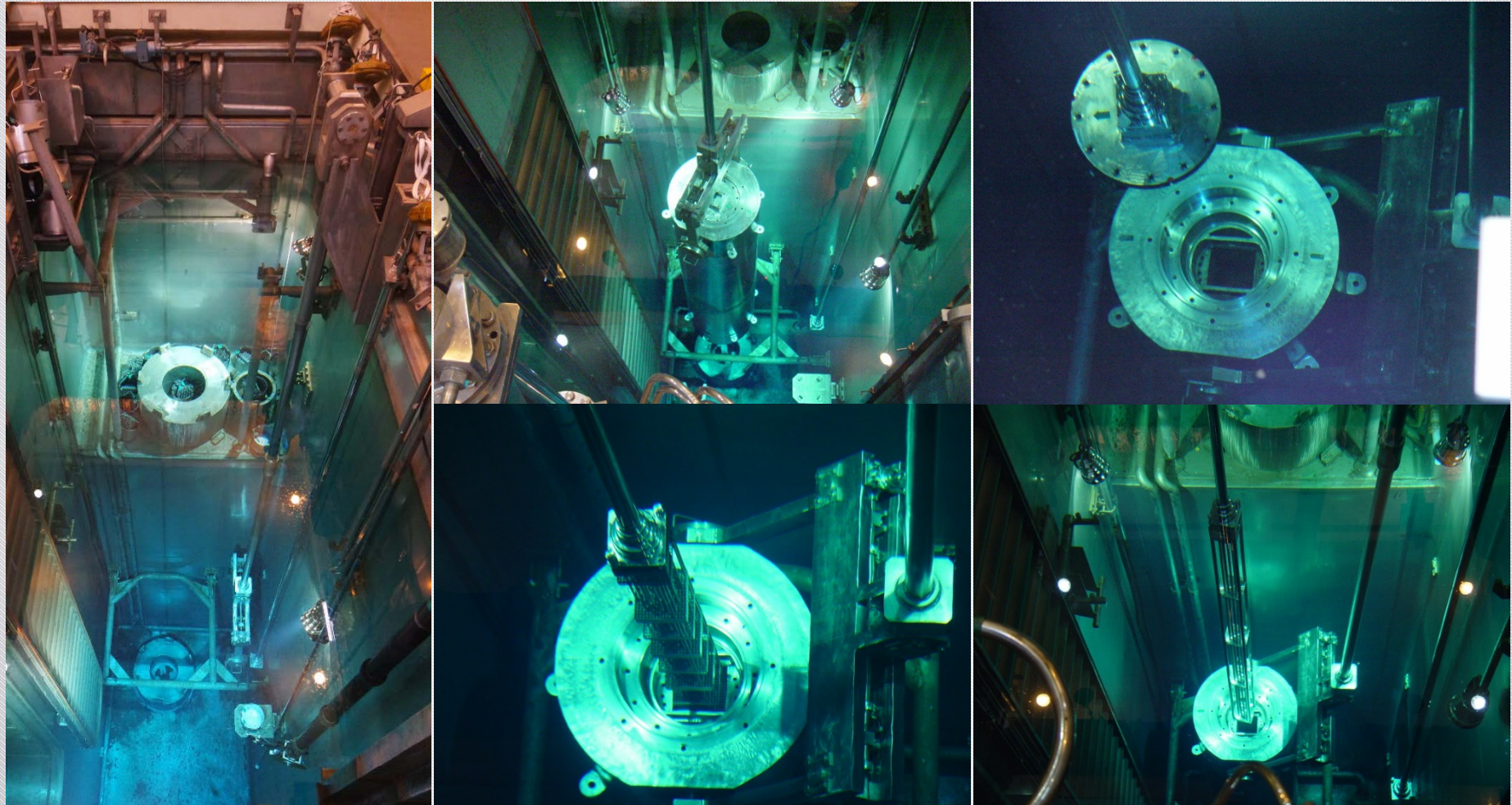
- **No.3 pool (9403)**

- Dismantling & Inspection
- 7.5x3.9x15.5 (m)



## 02 Status of Spent Fuels in KAERI-PIEF

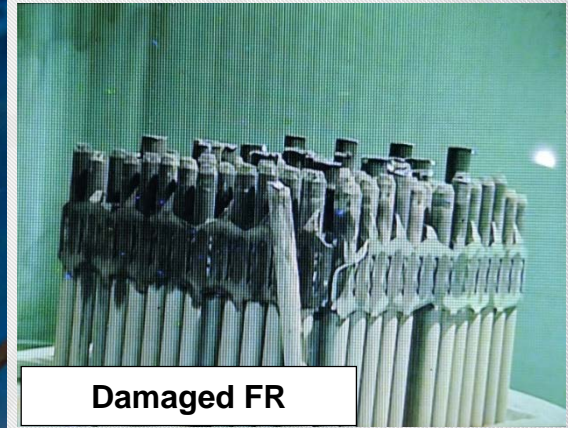
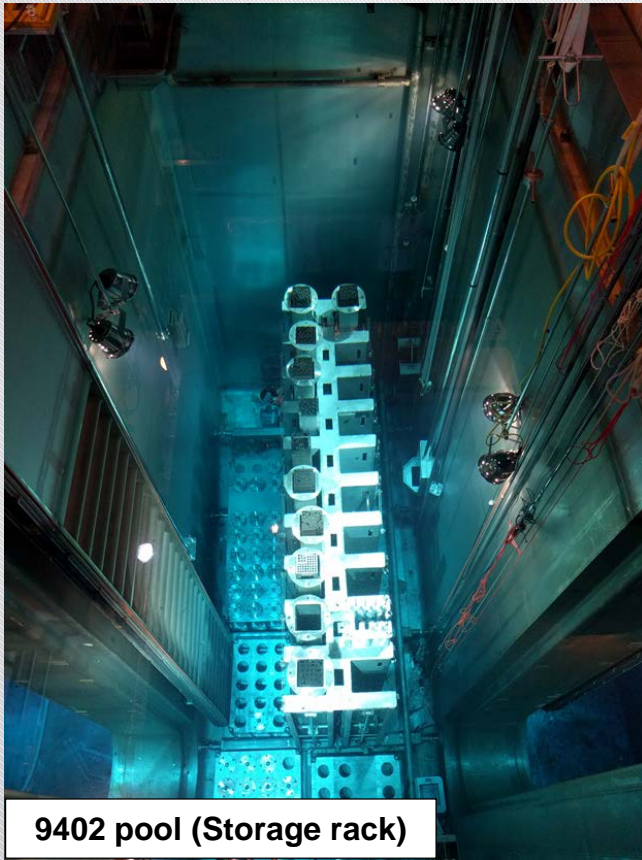
### » 9401 pool - Cask unloading





## 02 Status of Spent Fuels in KAERI-PIEF

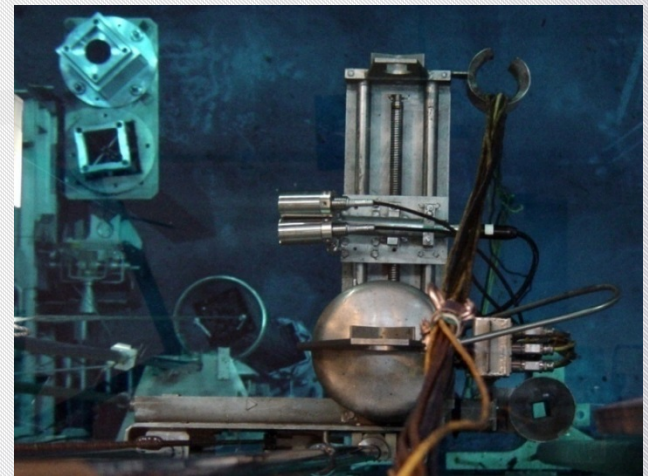
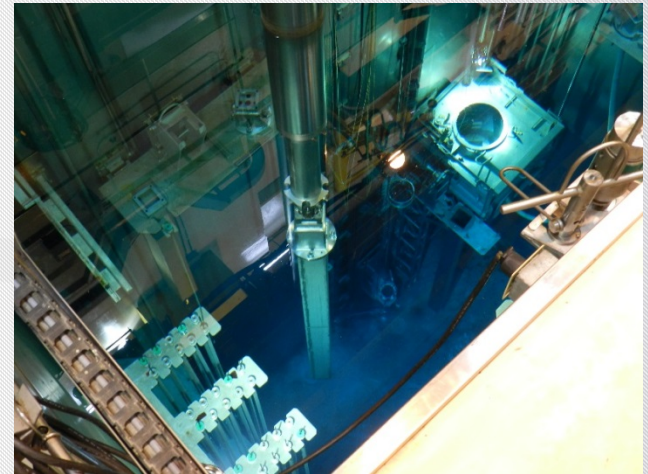
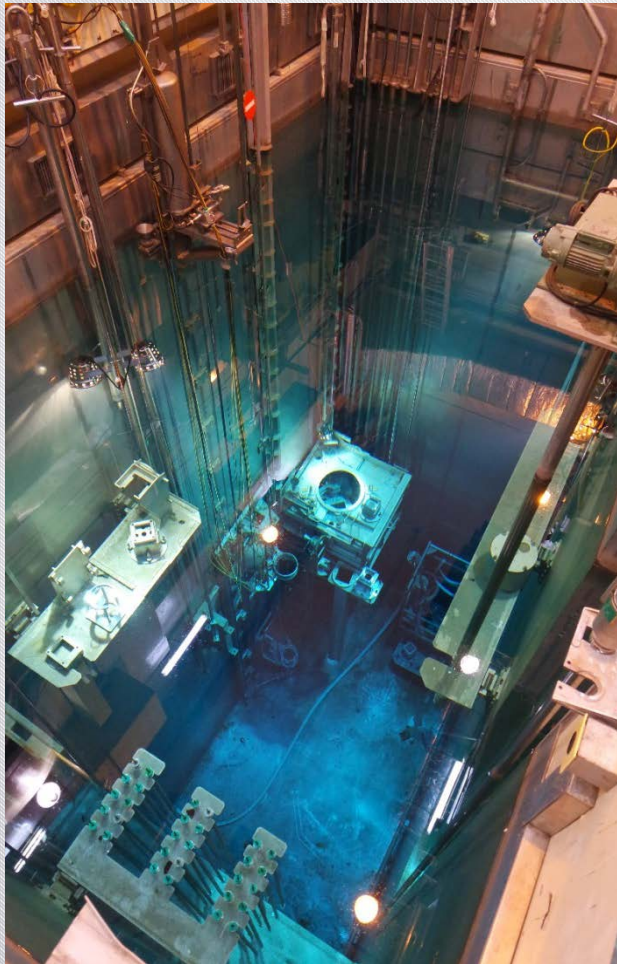
### » 9402 pool - **Storage of Fuel Assembly and Fuel Basket**





## 02 Status of Spent Fuels in KAERI-PIEF

### » 9403 pool - Dismantling & Inspection





## 02 Status of Spent Fuels in KAERI-PIEF

### » Information of Spent Fuels(SFs)

Status of SFs in PIEF	
Type	Location
1 Intact Fuel Assembly	FA basket (storage rack)
7 Damaged FA (without top nozzle)	FA basket (storage rack)
Intact and damaged Fuel Rods	FR basket (storage rack)
Rod fragments / mounted specimen	Rod Cut Container(RCC)

- ~ 1700 fuel rods received from Nuclear Power Plant (stored in the storage pool)

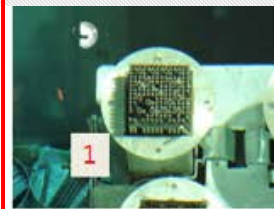
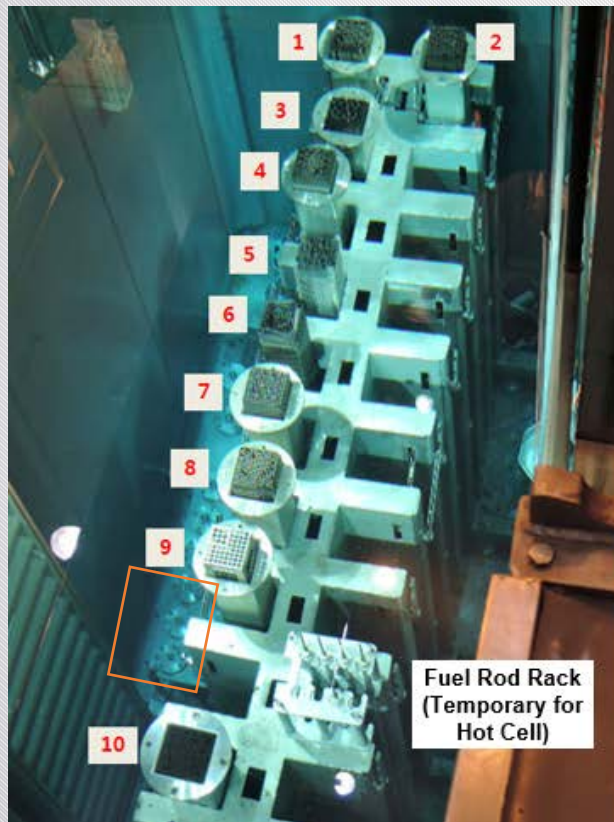
- Characteristics of fuel rods

- ✓ Max. diameter of spent fuel rod :  $\leq 10.7$  mm
- ✓ Max. length of spent fuel rod :  $\leq 4094.5$  mm
- ✓ Max. enrichment of U-235 : assumed less than 5 wt%
- ✓ Max. discharge pin burn-up : assumed less than 60 GWd/tU
- ✓ Min. cooling time : assumed longer than 6 months

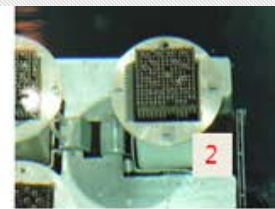


# 02 Status of Spent Fuels in KAERI-PIEF

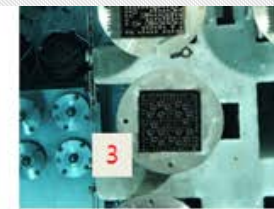
## » Fuel Storage Rack



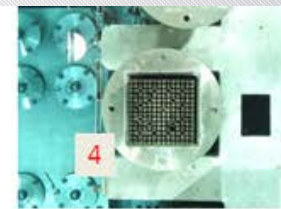
SNF w/o Top nozzle  
(14x14, W-STD, C15)



SNF w/o Top nozzle  
(14x14, W-STD, A39)



SNF w/o Top nozzle  
(16x16, KOFA, J44)



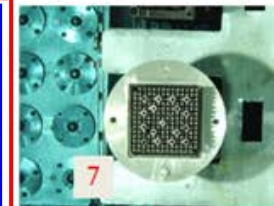
SNF w/o Top nozzle  
(14x14, W-STD, J14)



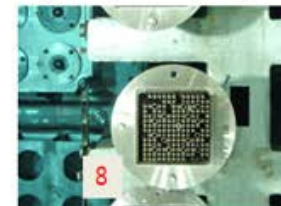
Intact Fuel Rod Basket  
(39 FR's)



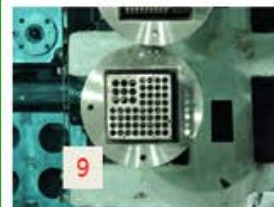
Intact SNF  
(14x14, W-STD, F02)



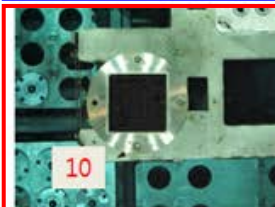
SNF w/o Top nozzle  
(14x14, W-STD, A17)



SNF w/o Top nozzle  
(14x14, W-STD, G23)



Damaged Fuel Rod Basket  
(41 FR's)



SNF w/o Top nozzle  
(17x17, V5H, K23)



Rod Cut Containers  
for fragment/specimen

1 intact FA

7 damaged FAs

2 Fuel Rod Baskets

Rod Cut Containers



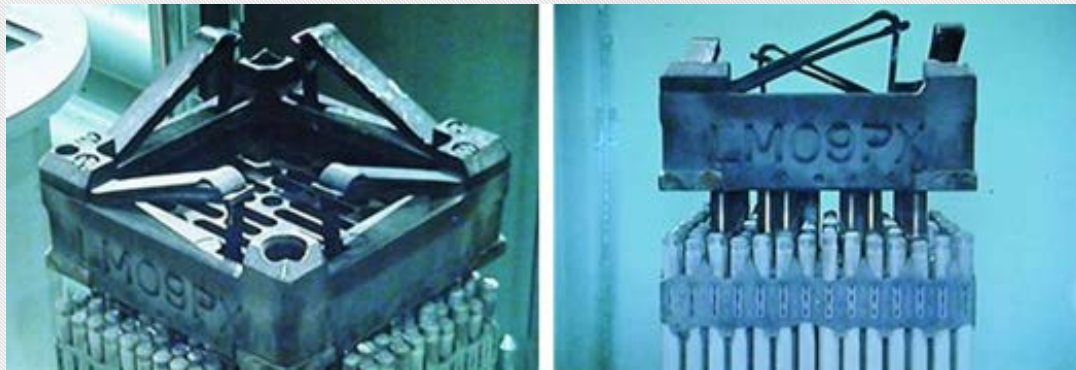
# 02 Spent Nuclear Fuels in KAERI-PIEF

## » Intact Spent Fuel Assembly

### ▪ 1 Intact Spent Fuel Assembly

- ✓ The safe handling of intact FA can be achieved without an additional task because of the top nozzle
- ✓ The transportation of intact FA using an open can will be adopted if there are no failed or defective fuel rods

\*WH STD 14 x 14 fuel assembly type (Kori Unit 1)



### Scenario for intact FA

Move to a visual inspection stand



Failed or defective Fuel Rods in FA

Yes

1. Dismantling of FA – 2. Extracting the failed or defective rods  
3. Inserting stainless steel dummy rods – 4. Repair of FA

No

Transportation of FA using an open can



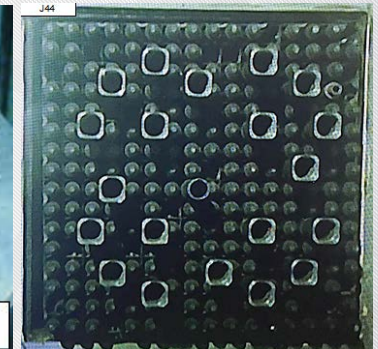
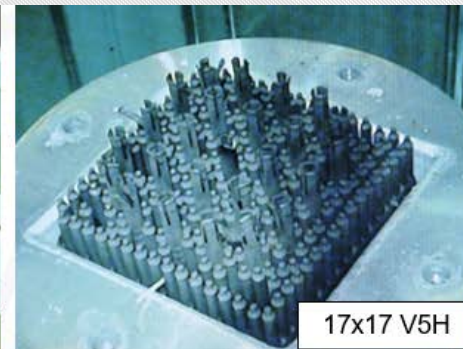
# 02 Spent Nuclear Fuels in KAERI-PIEF

## » Damaged Spent Fuel Assembly

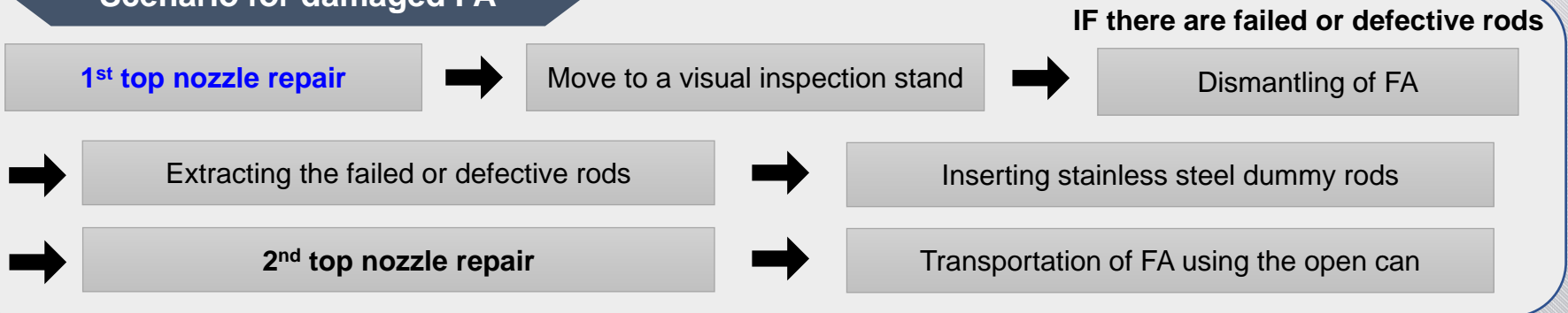
### ▪ 7 Damaged Spent Fuel Assemblies without top nozzle

- ✓ The top nozzle was removed to extract the fuel rods for the purpose of research in PIEF
- ✓ The repair of top nozzle is the first step to achieve the handling of FAs in the pool

\*Examples of damaged fuel assemblies without the top nozzle



### Scenario for damaged FA



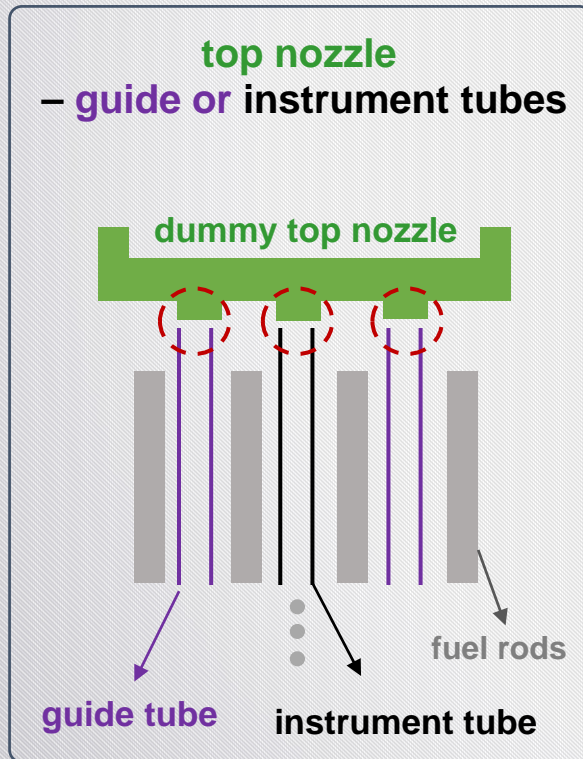


## 02 Spent Nuclear Fuels in KAERI-PIEF

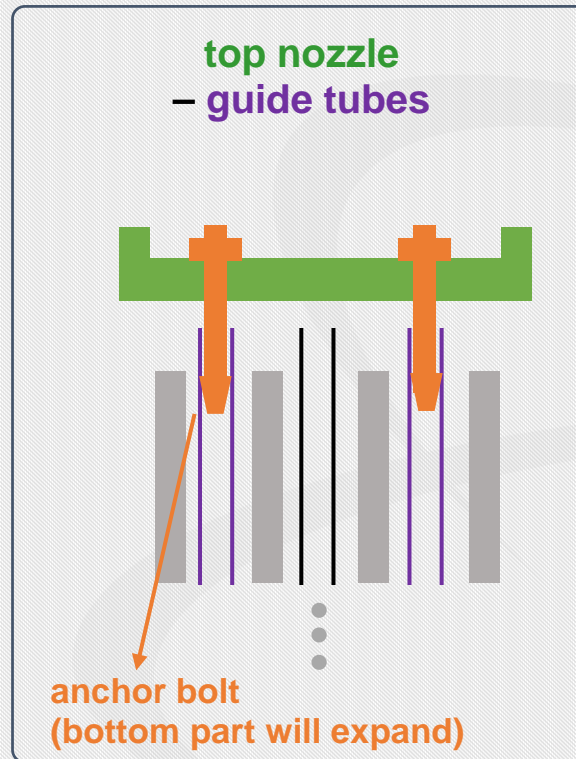
### » Damaged Spent Fuel Assembly

- Possible solutions for the top nozzle restoration

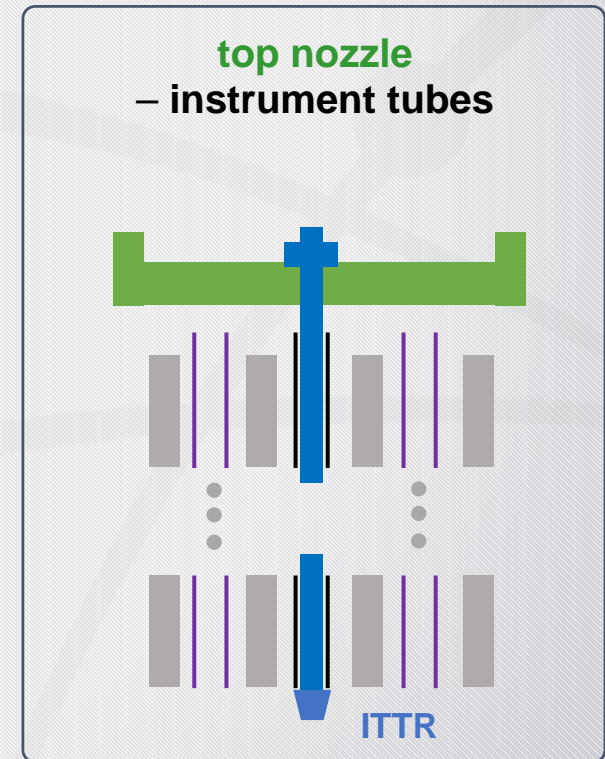
#### (1) Welding



#### (2) Anchor bolt



#### (3) Instrument Tube Tie Rod, ITTR



: if these methods are not applicable,  
the fuel rod containers (ex. Quiver) will be used after extracting all fuel rods.



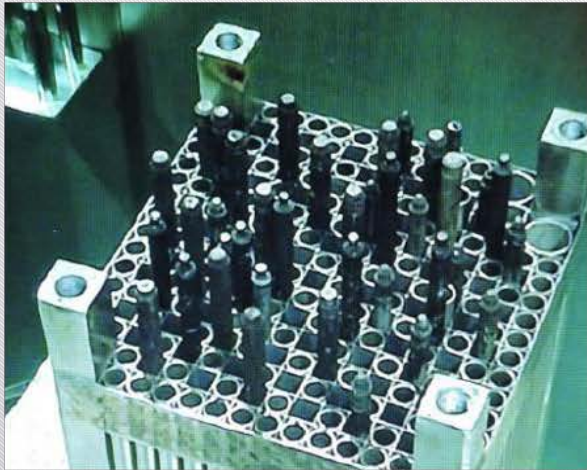
# 02 Spent Nuclear Fuels in KAERI-PIEF

## » Intact and Damaged Fuel Rods

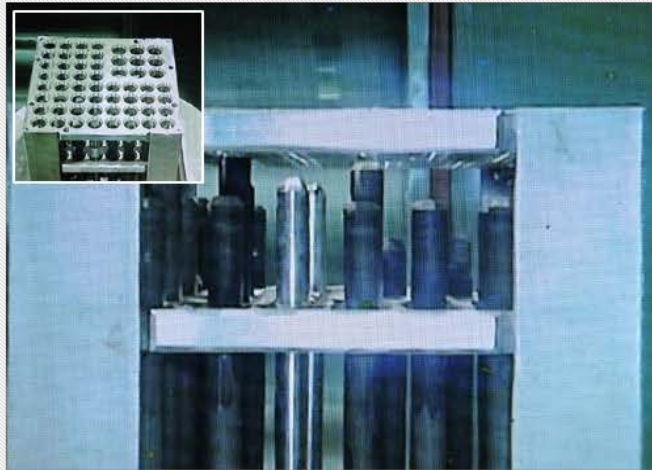
### ▪ Fuel Rod Basket in the storage rack

- ✓ Intact and damaged fuel rods are stored in the fuel rod baskets, respectively
- ✓ Some fuel rods are stored in a storage rack in pool #3

FRs(Intact) in Basket



FRs(Damaged) in Basket



FRs in Storage Rack





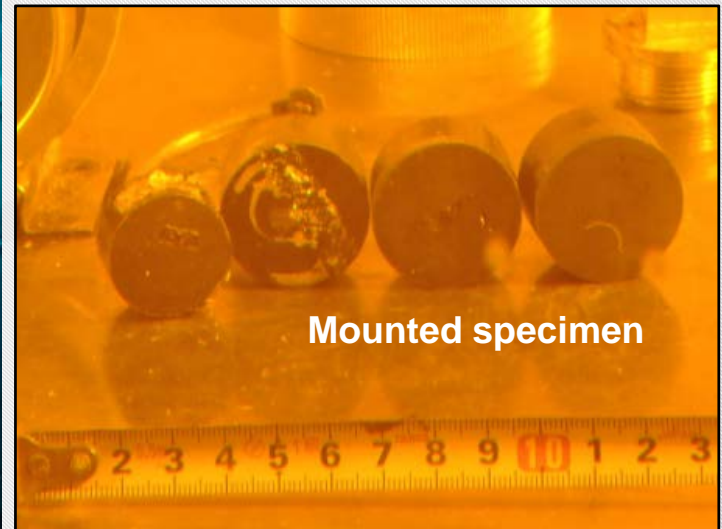
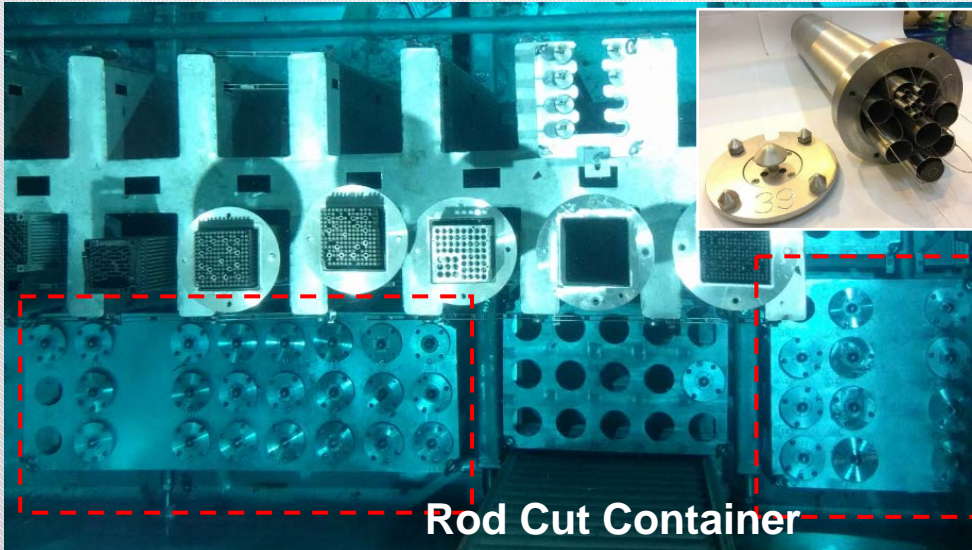
# 02 Spent Nuclear Fuels in KAERI-PIEF

## » Fragments / Specimens

### ▪ Rod Cut Container(RCC) and specimen cask

- ✓ Fragments and mounted specimens are stored in the RCC and specimen cask
- ✓ The length of **fragment**: less than 45 mm
- ✓ The size of **mounted specimen** will be reduced through a coring process (Diameter  $\leq 20$  mm)

### Fragments / Specimens





# 02 Spent Nuclear Fuels in KAERI-PIEF

## » Fuel Rods and Fragments/Specimens

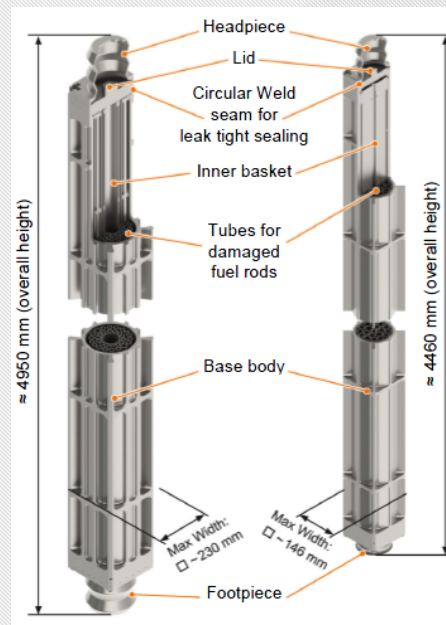
### ■ Possible solutions for transportation of fuel rods and fragments/specimens

- ✓ Following commercial spent fuel containers can be adopted.

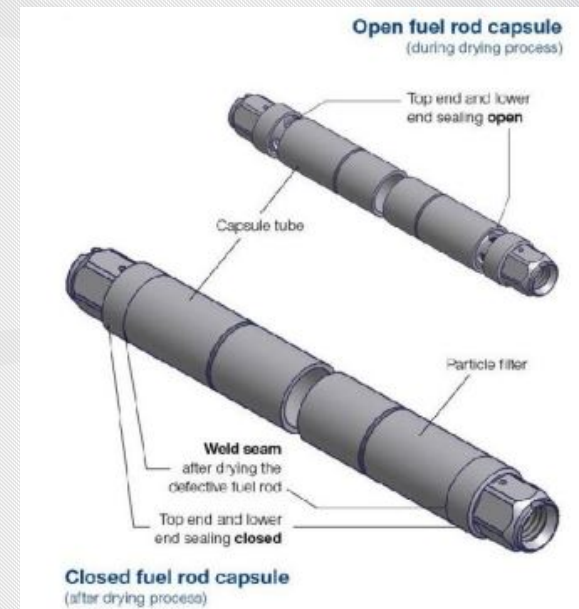
**Quiver System  
(Westinghouse)**



**Integrated Quiver  
(GNS)**



**Opened/closed fuel rod capsules  
(Framatome)**



#### < References for image >

[1] Westinghouse Quiver Digital Handout, <http://www.westinghousenuclear.com/>

[2] GNS IQ integrated Quiver System. <http://www.gns.de/language=en/29870/quiver-iq>

[3] Matthew French, David Nixon, Roger Thetford, Mark Cowper, "Packaging of Damaged Spent Fuel", Amec Foster Wheeler, 204895-UA00, 2016.



## 03 Summary and Future Works

### » Conclusion

- Status of spent fuels in KAERI-PIEF has been introduced.
- KAERI-PIEF has been performed the preliminary study with Korea Hydro & Nuclear Power (KHNP) and nuclear power companies.
- To achieve the safe transportation and long-term storage of spent fuels in the NPP storage pool or interim storage site, it is essential to determine the optimum solutions based on the conditions of FAs, fuel rods, and fragments/specimens.
- KAERI will determine the optimum repair and canning solutions for FAs, fuel rods and fragments/specimens stored in PIEF.





Korea Atomic Energy  
Research Institute

감사합니다

Thank you for attention