Retrieval of Damaged Components form Experimental Fast Reactor Joyo Reactor Vessel

June . 8th , 2010

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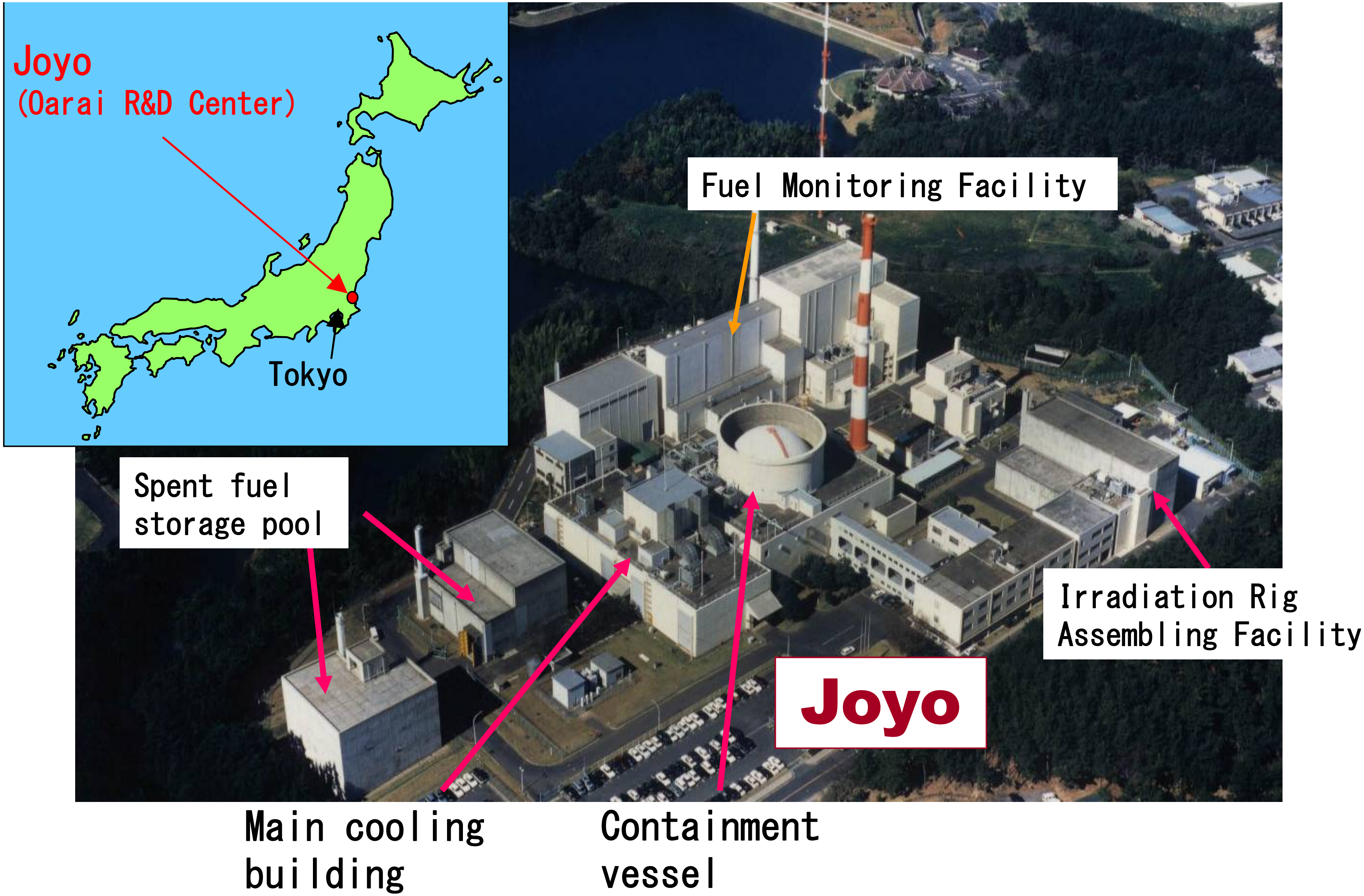
Japan Atomic Energy Agency (JAEA)

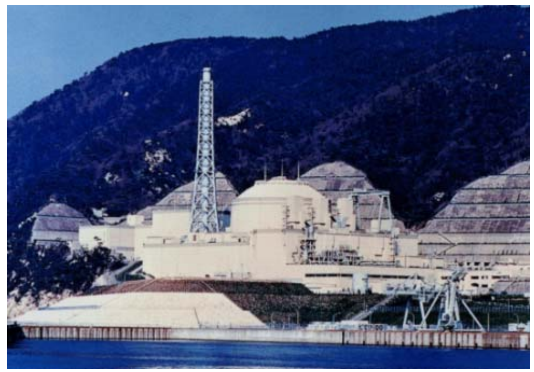
Experimental fast reactor Joyo



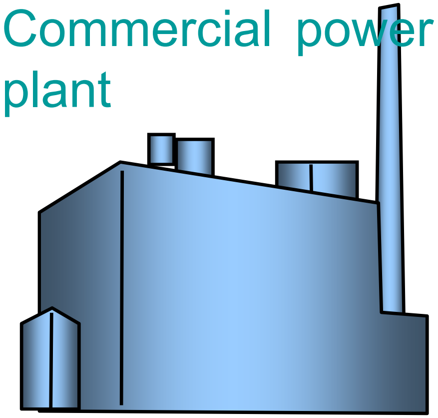
Role of JOYO

To confirm the performance of sodium cooled FBR power plant

Prototype fast breeder reactor power plant MONJU
280MWe (714MWt)



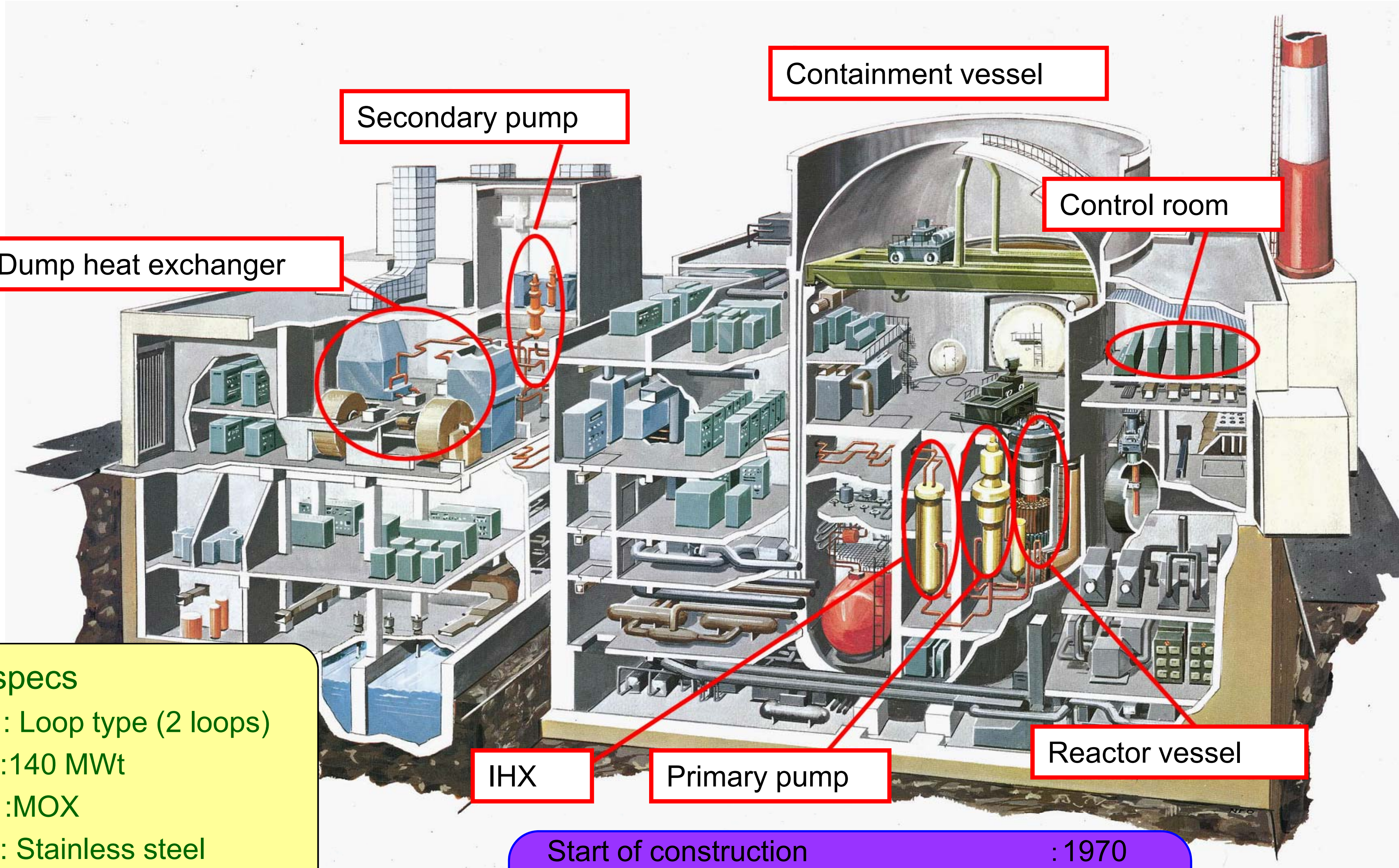
Commercial power plant



Experimental fast reactor JOYO
140MWt

- To confirm the principle of sodium cooled FBR
- To establish operation, maintenance technology
- Irradiation for fuels and materials development using fast neutron field

Outline of JOYO



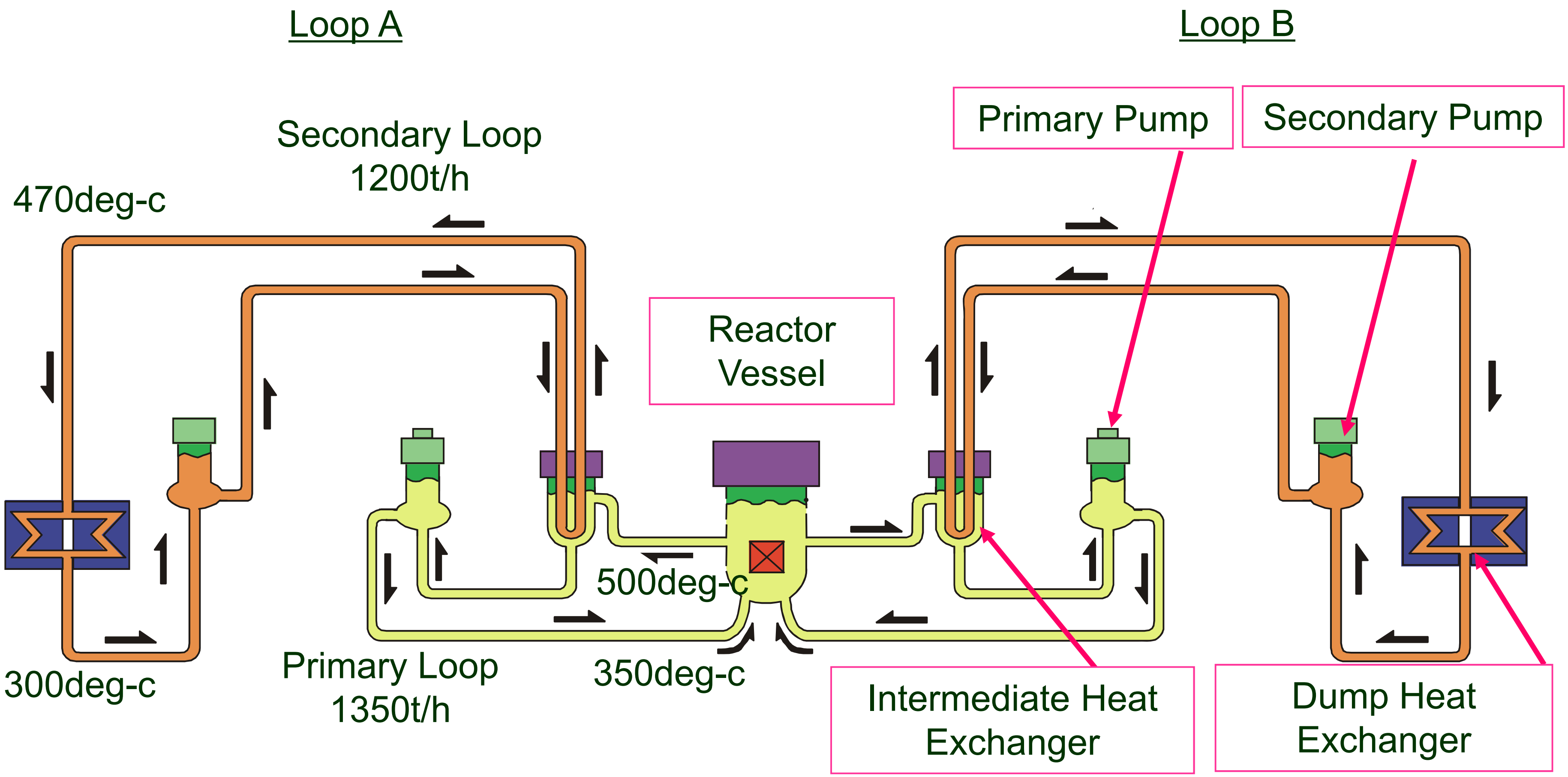
Major specs

Type : Loop type (2 loops)
Rated power :140 MWt
Fuel :MOX
Core Structure : Stainless steel
Coolant : Liquid sodium
Core diameter : 80 cm
Core height : 50 cm

Start of construction : 1970
Operation（breeding core : MK - I) : 1978
(irradiation core : MK-II) : 1982
Upgrading core（MK-III）criticality : July 2003
Start of irradiation with MK-III core : May 2004

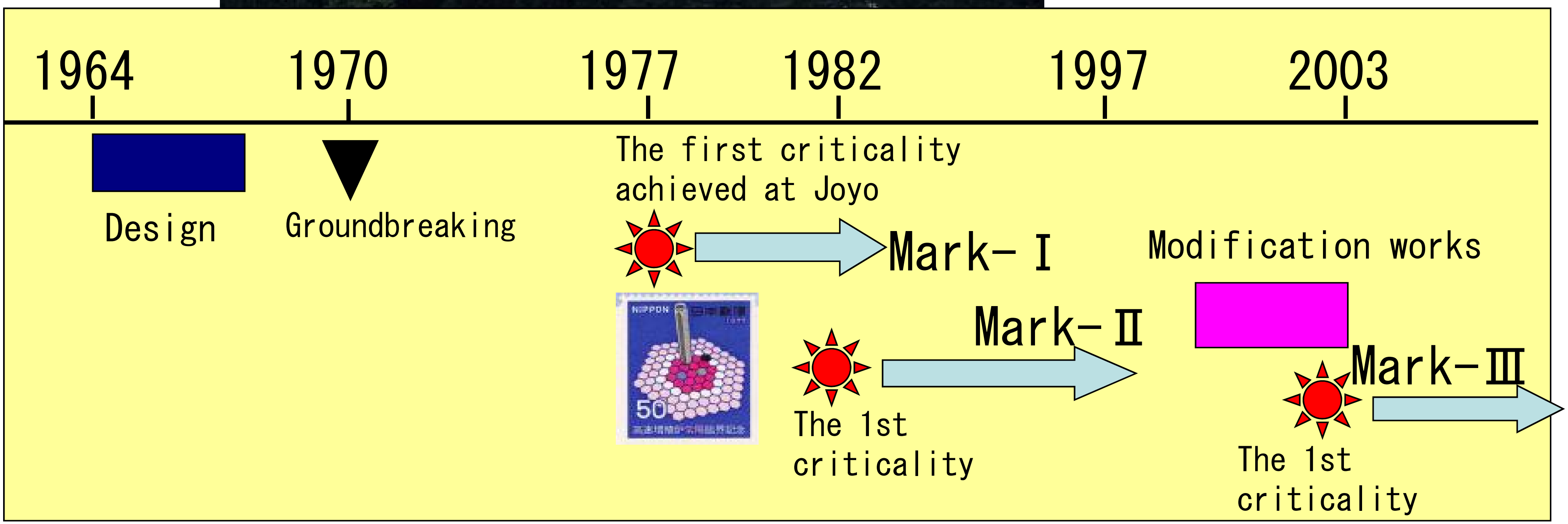
4

JOYO heat transport system



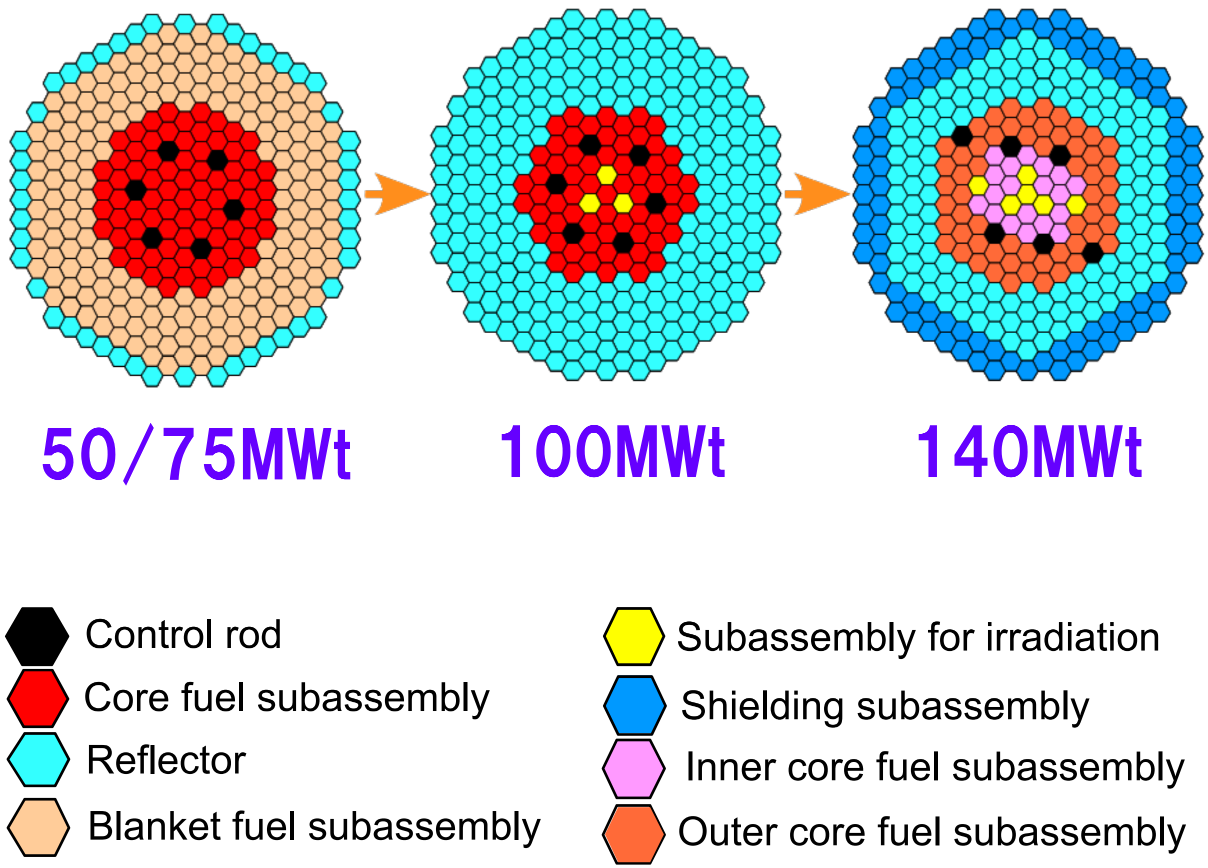
Cooling system type : Loop type
Number of main cooling system : 2
Heat Removal : Air Cooling

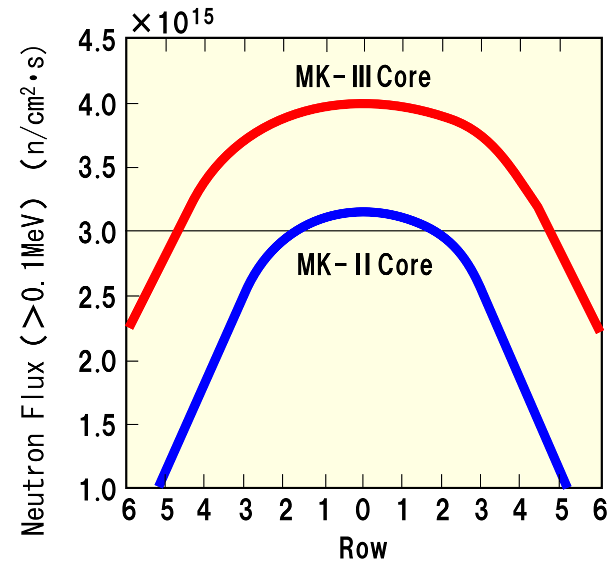
History of Joyo



Upgrading of the Joyo cores

MK-I core	MK-II core	MK-III core
Breeder core	Irradiation core	Upgraded Irradiation core
50/75MWt	100MWt	140MWt

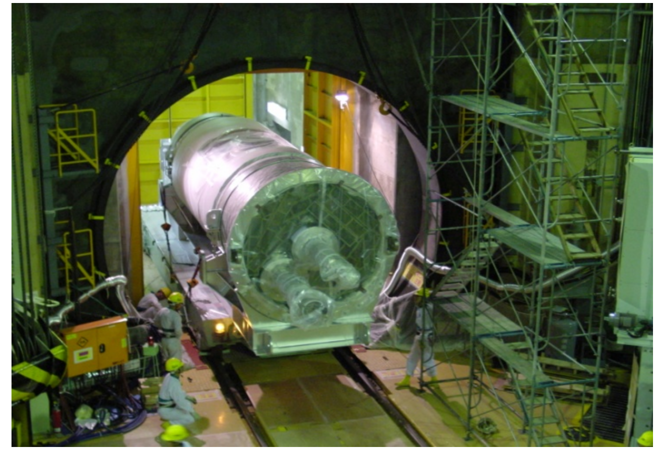




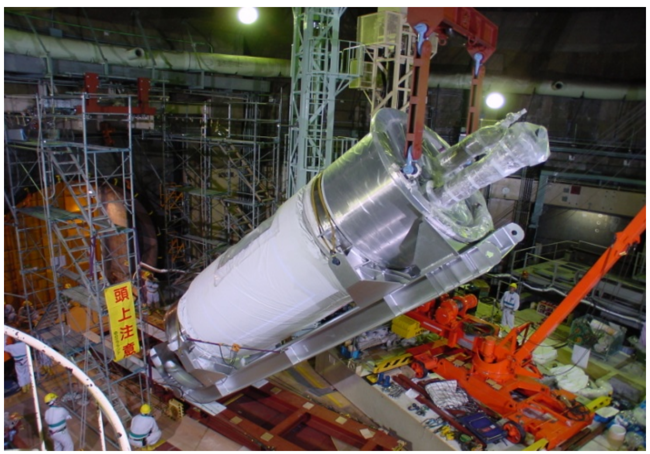
Installation of New Main IHX

Transport from Warehouse to Maintenance Building

Move from Maintenance Building to RCV

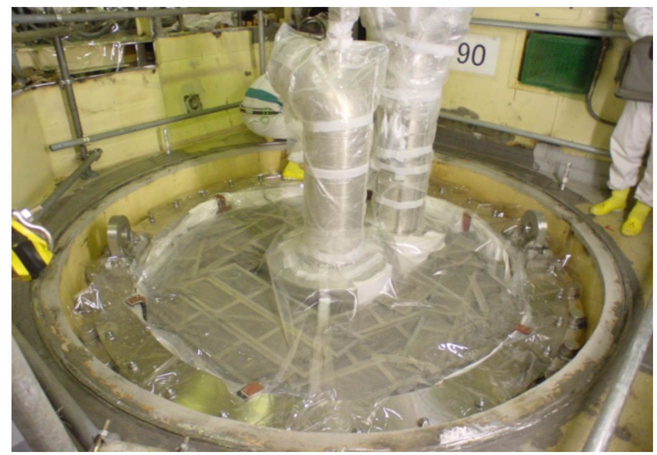


Move inside RCV



Stand-up

Lift-down



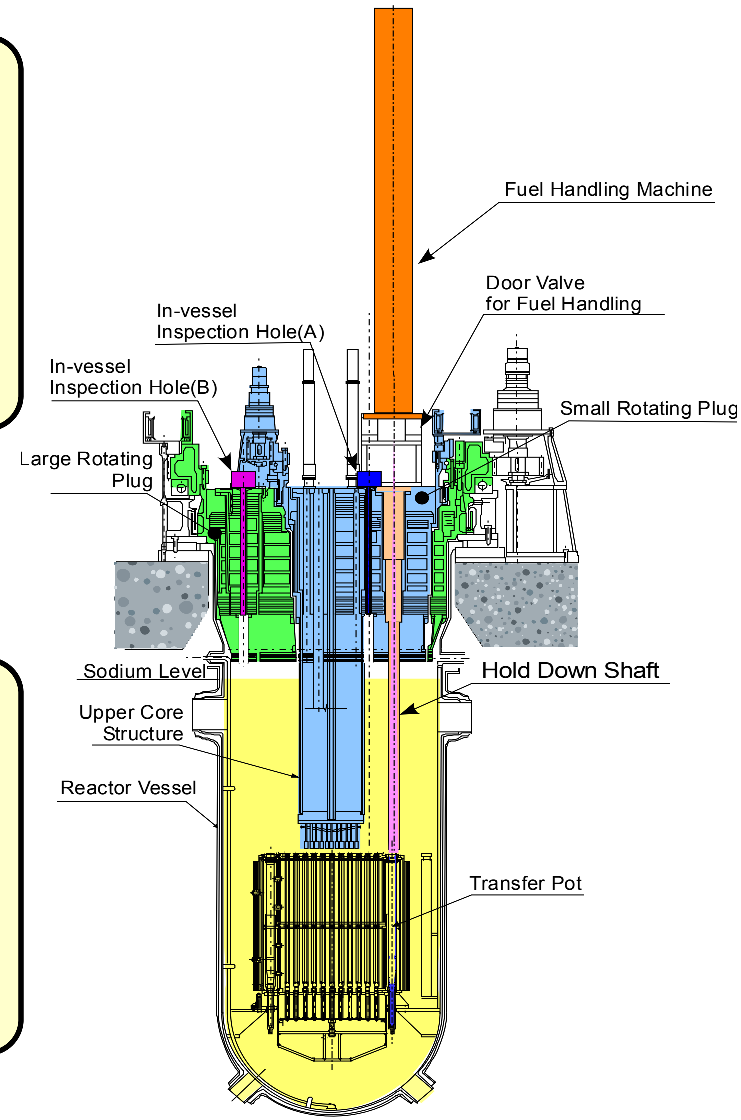
Installation Completed

Background

- On June 11th 2007, fuel handling machine was set up on the rotating plug (R/P) as a refueling preparation.
- The measured load of hold down shaft indicated abnormal decrease in the R/Ps jack down operation.

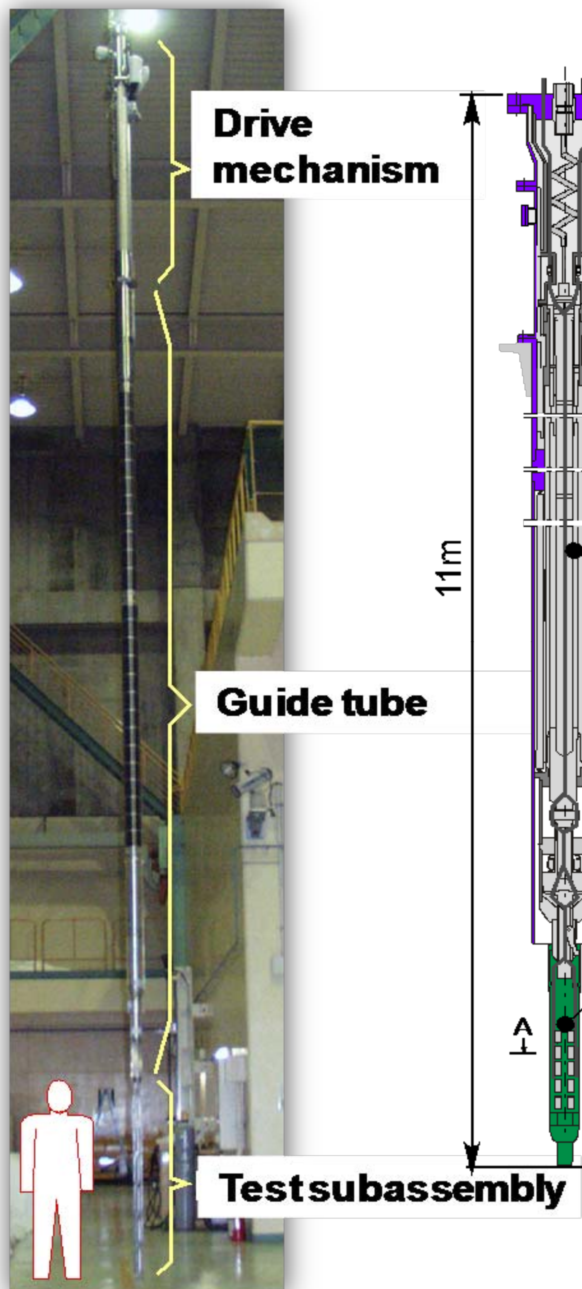
It was suspected that there was an obstacle under the hold down shaft.

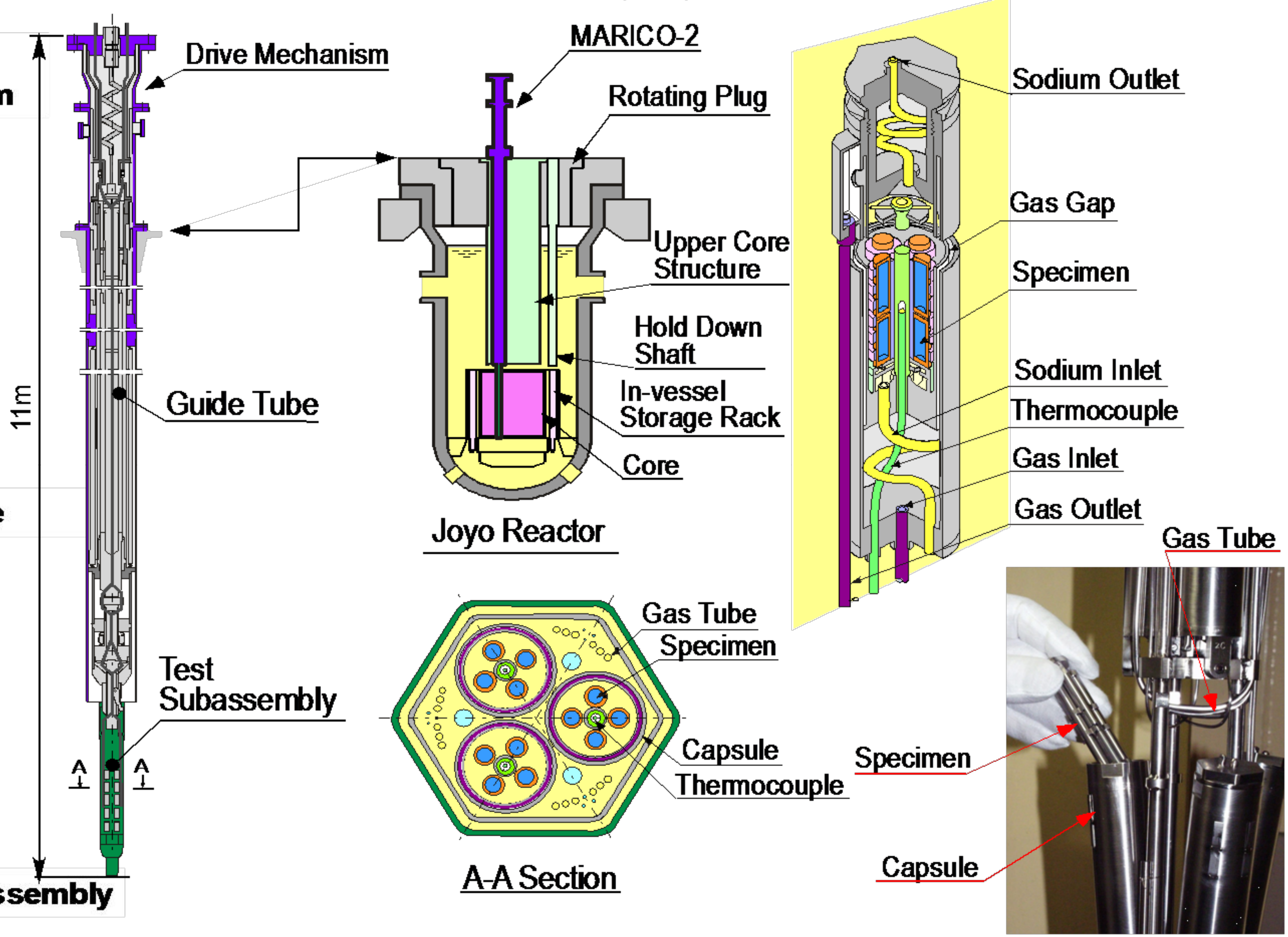
- The in-vessel storage rack under the hold down shaft stored an irradiation rig “MARICO-2”.
- As a result of visual inspection, an obstacle around in-vessel storage rack was identified as the MARICO-2 test subassembly.



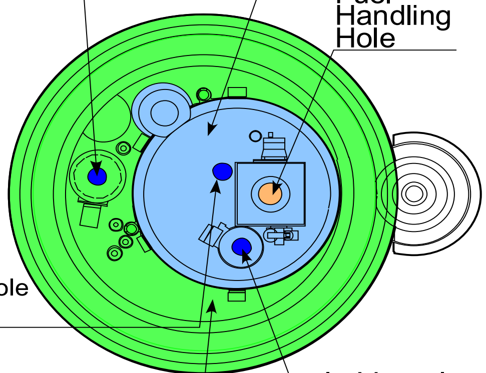
Structure of MARICO-2

MARICO : MAterial testing RIg with temperature COntrol

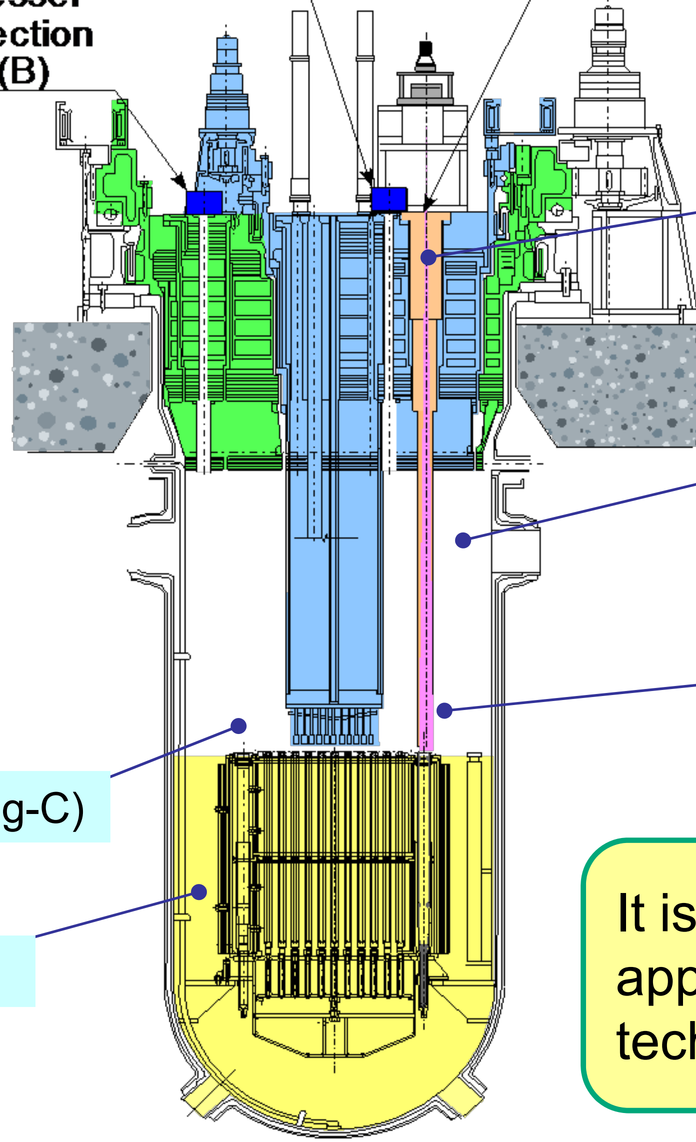




In-Vessel Inspection of Sodium cooled Fast Reactor



Top view of Rotating Plug



① Access route is limited

- In-Vessel inspection Hole(A),(B) : Φ110
- Fuel Handling Hole : Φ164
- Auxiliary Hole for C/R : Φ150

② Inert Atmosphere: Ar gas

- Maintain the boundary

③ High Radiation (200～300 Gy/h)

④ High Temperature (～200deg-C)

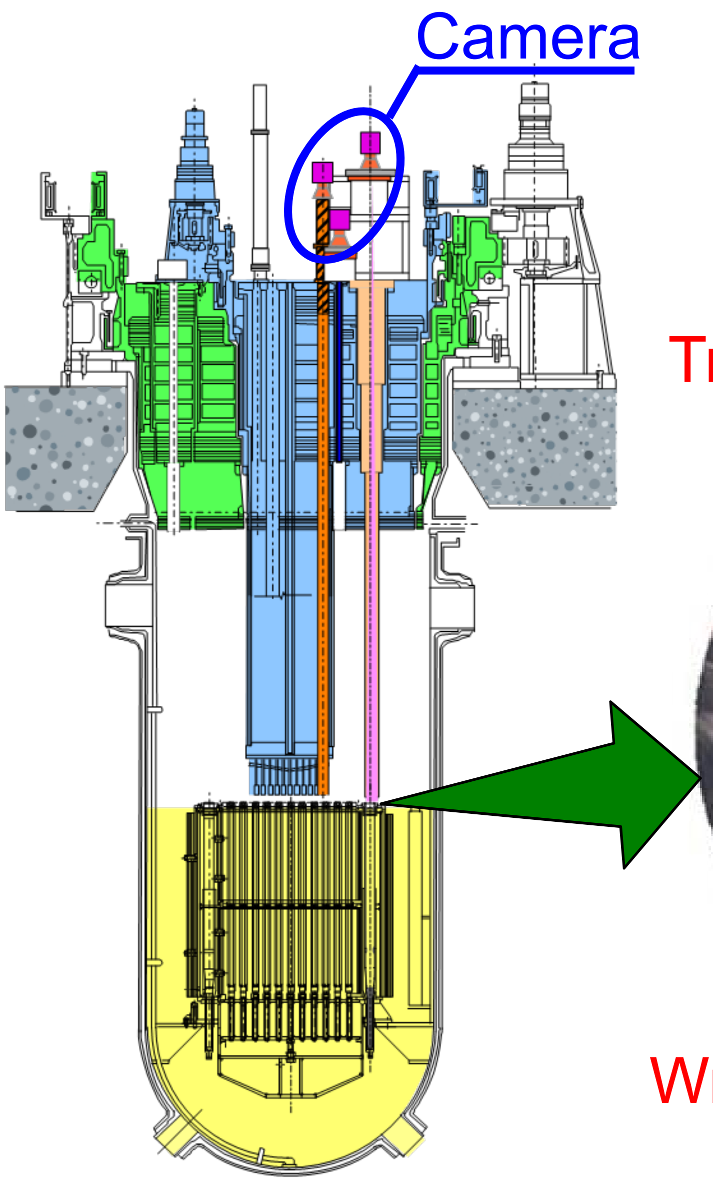
⑤ Opacity : Sodium

- Lower level of sodium

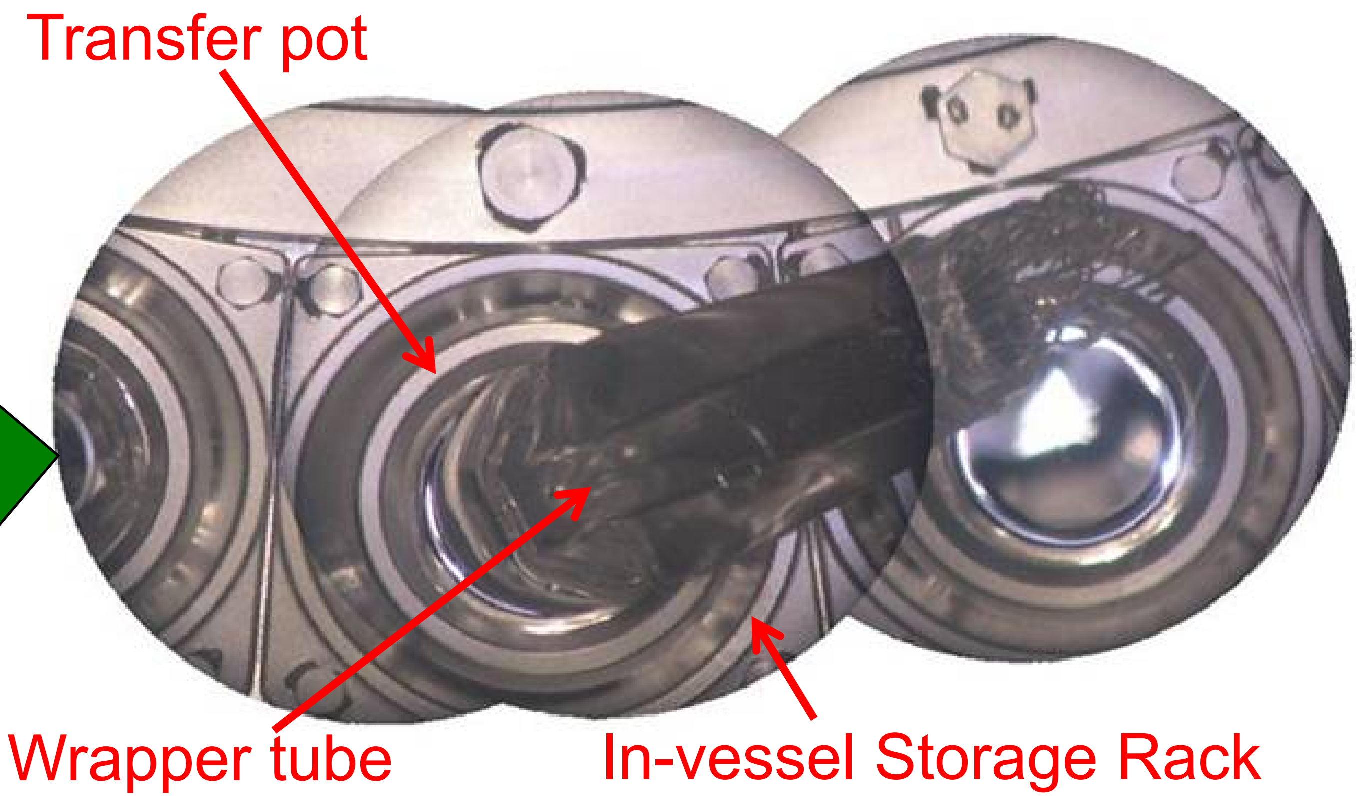
It is necessary to employ the appropriate inspection technology for fast reactor.

In-vessel visual observation by camera

- Bent MARICO-2 on in-vessel storage rack -

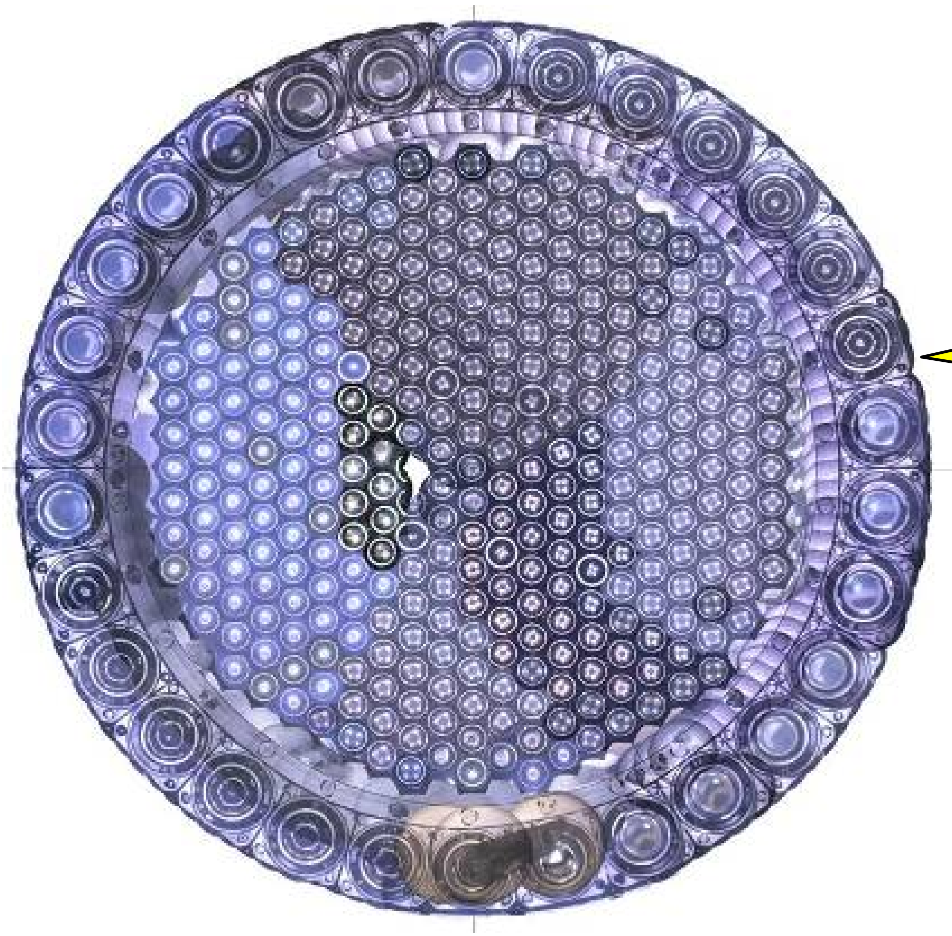


- Grasp the conditions of the transfer pot and the bent MARICO-2.

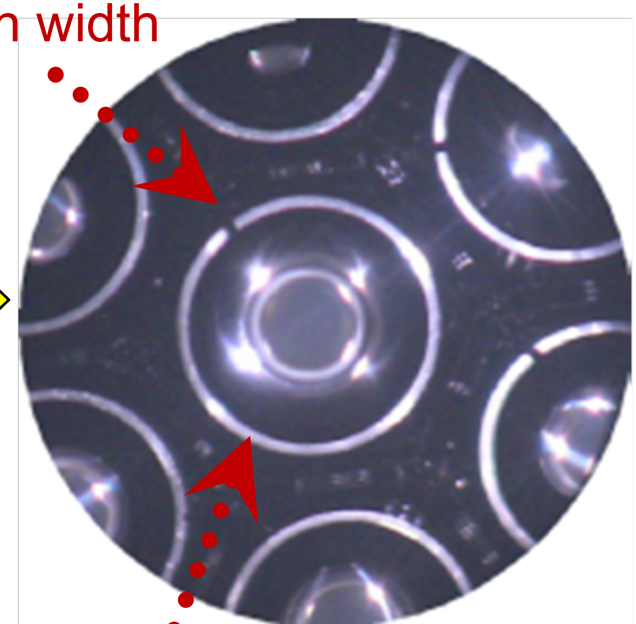


In-vessel visual observation by camera
- Top of the subassemblies and in-vessel storage rack-

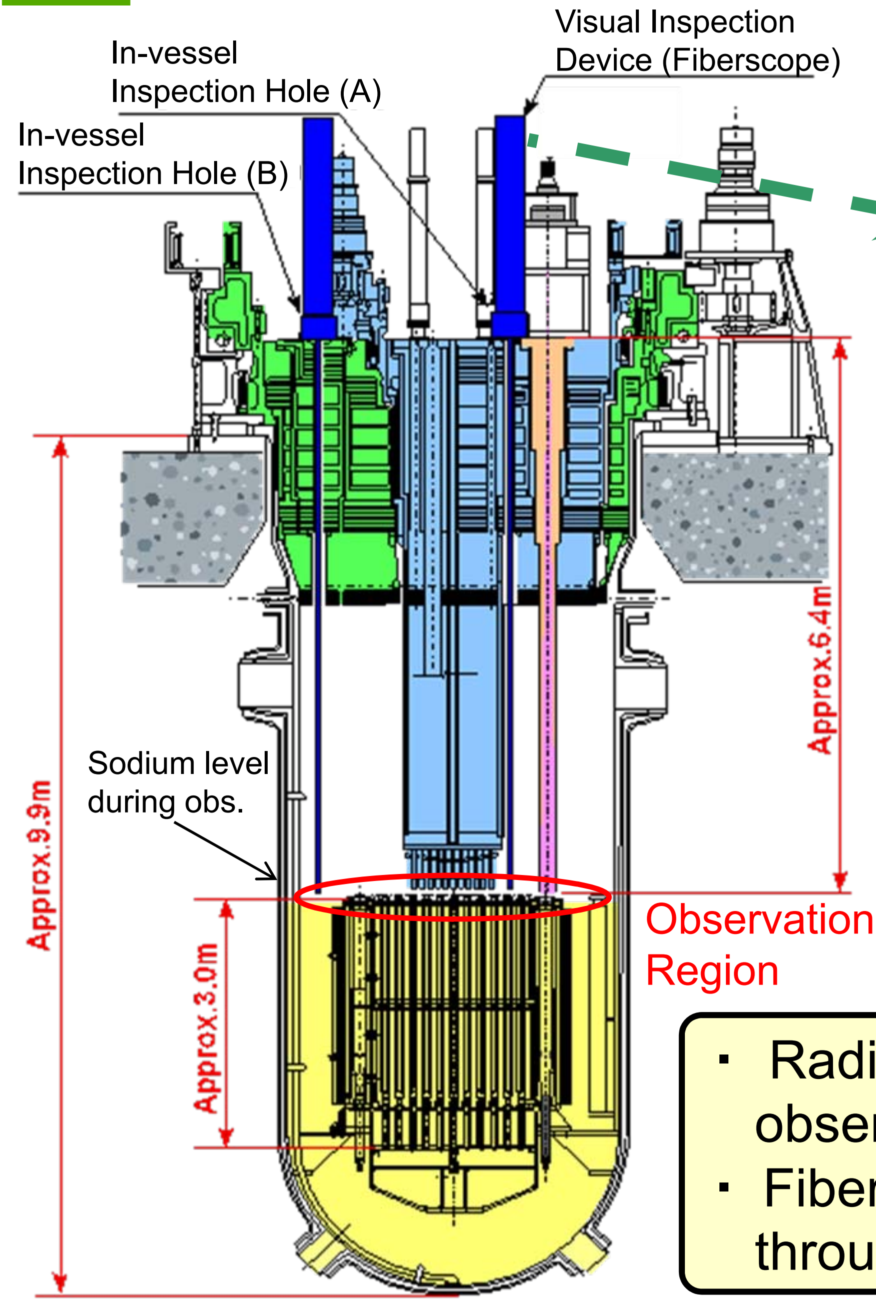
- No damage to each handling head of subassembly and in-vessel storage rack

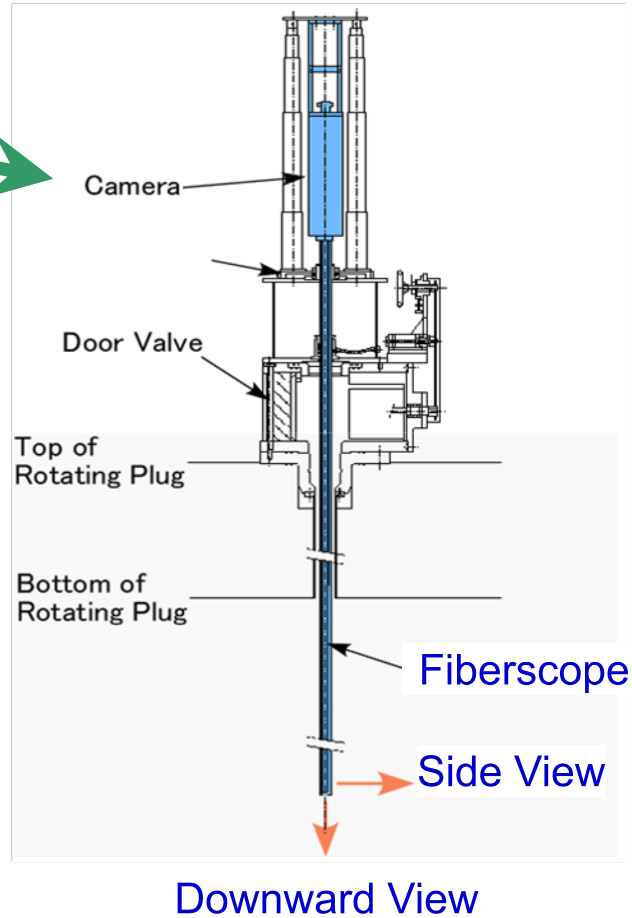


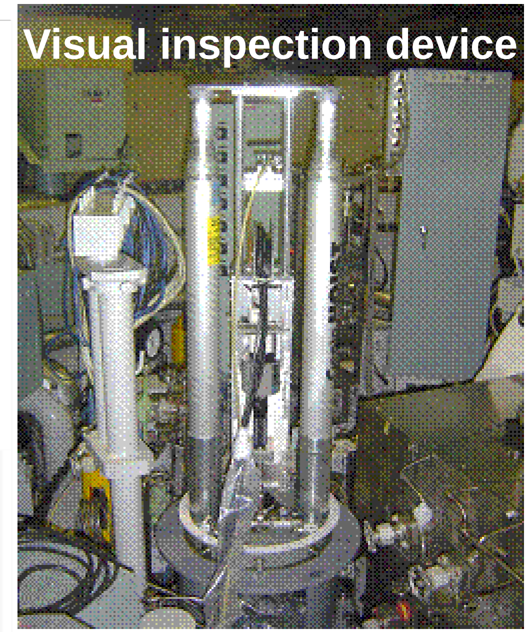
Composite photograph

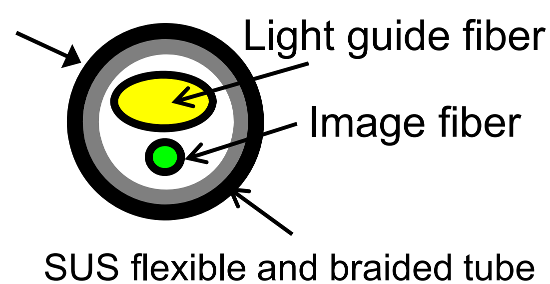


In-vessel visual inspection by fiberscope





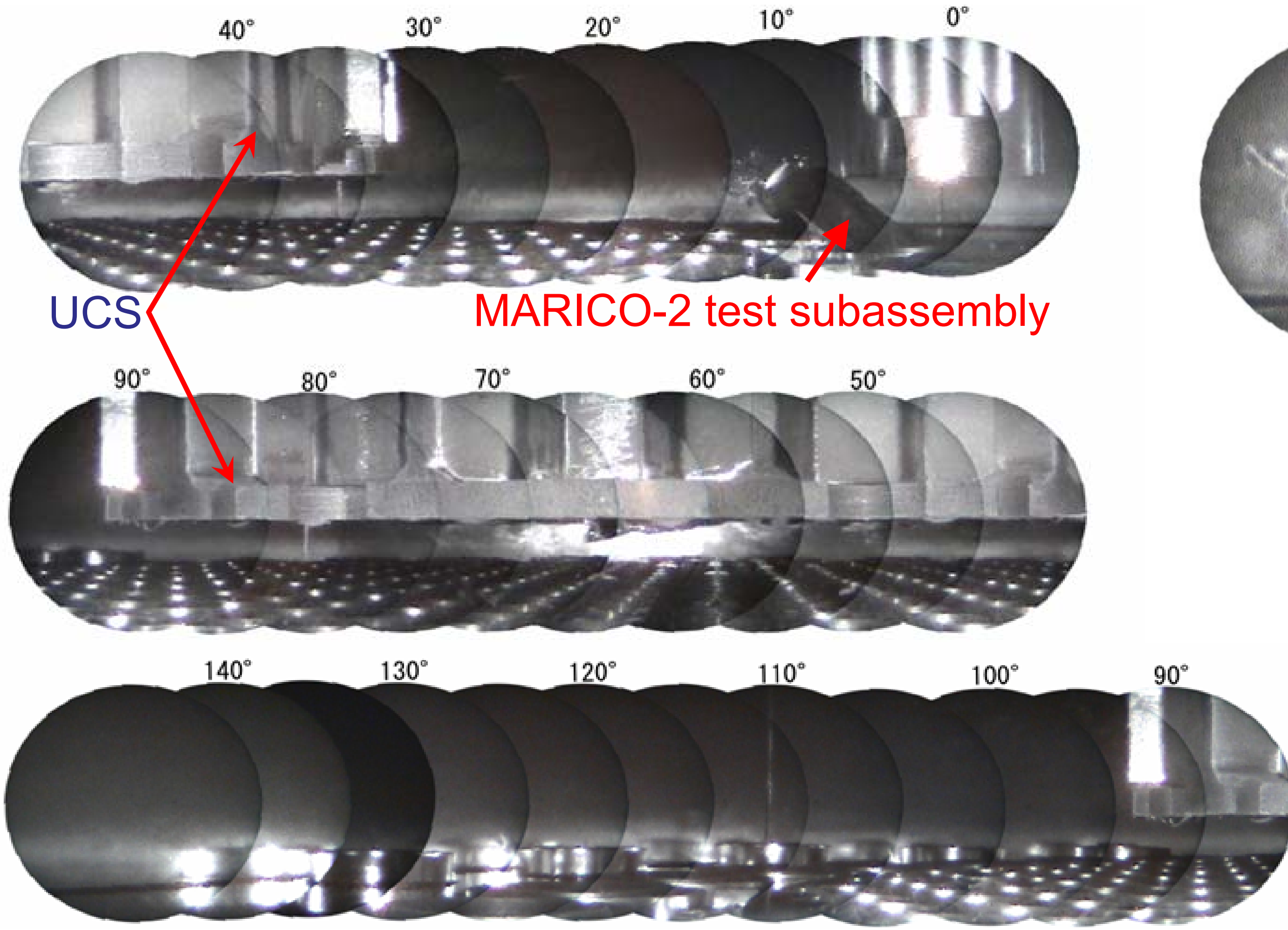


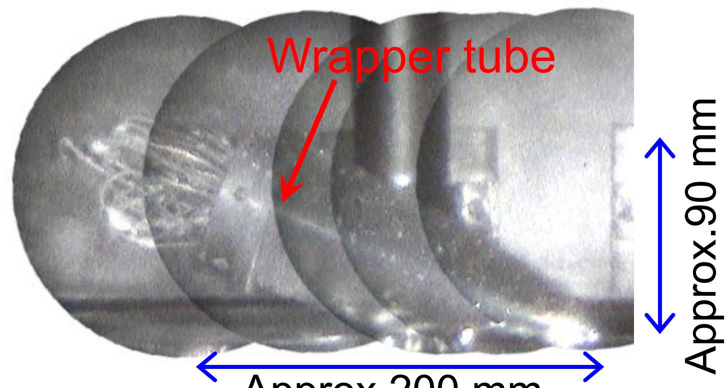


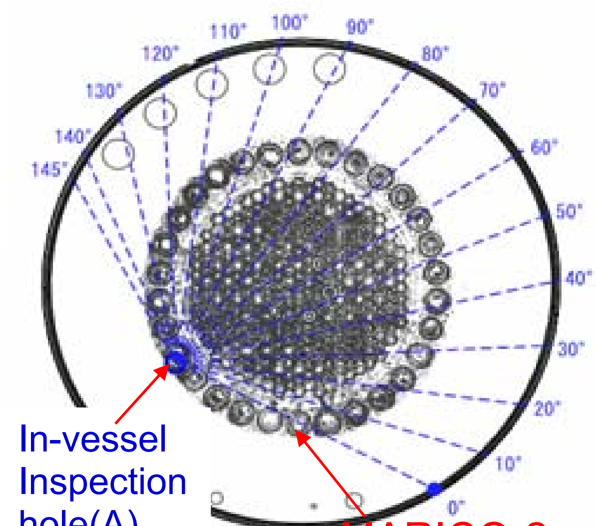
- Radiation resistant fiberscope was applied to observation.
- Fiberscope was inserted in the reactor vessel through the in-vessel inspection holes.

Results of observation by fiberscope

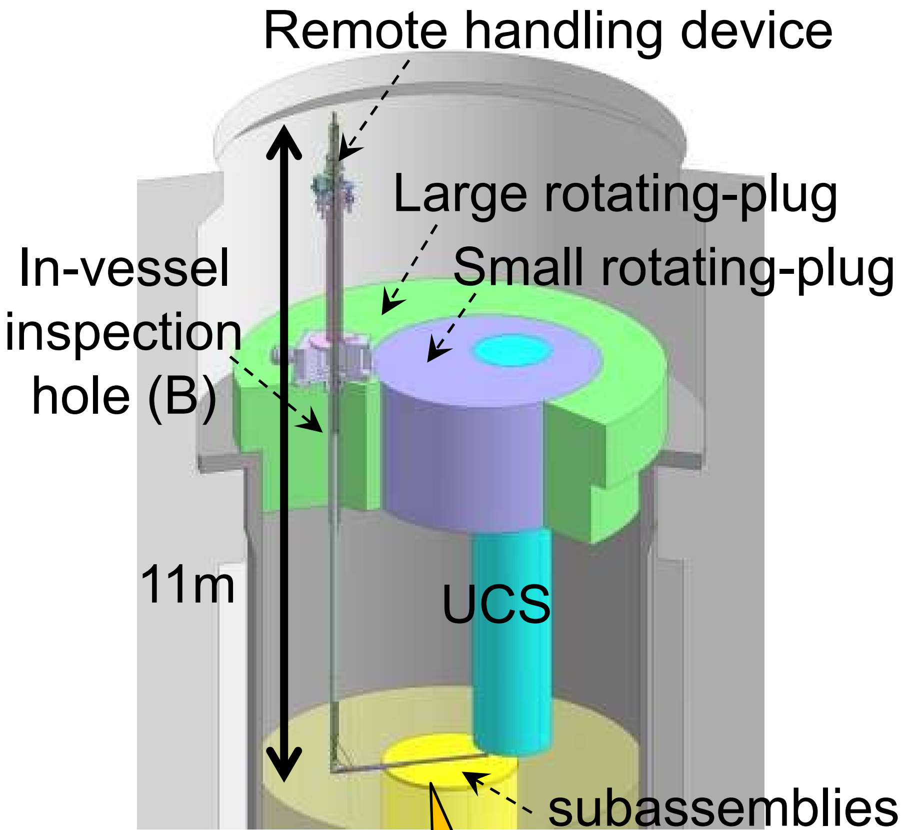
- Clear image was obtained by radiation resistant fiberscope.
- Grasp the condition of the bent MARICO-2.

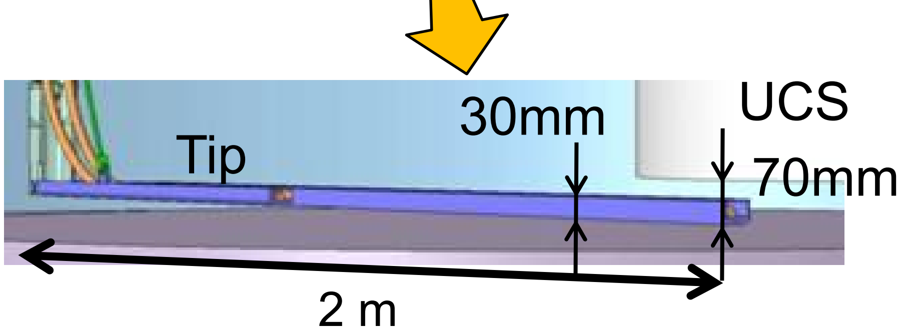


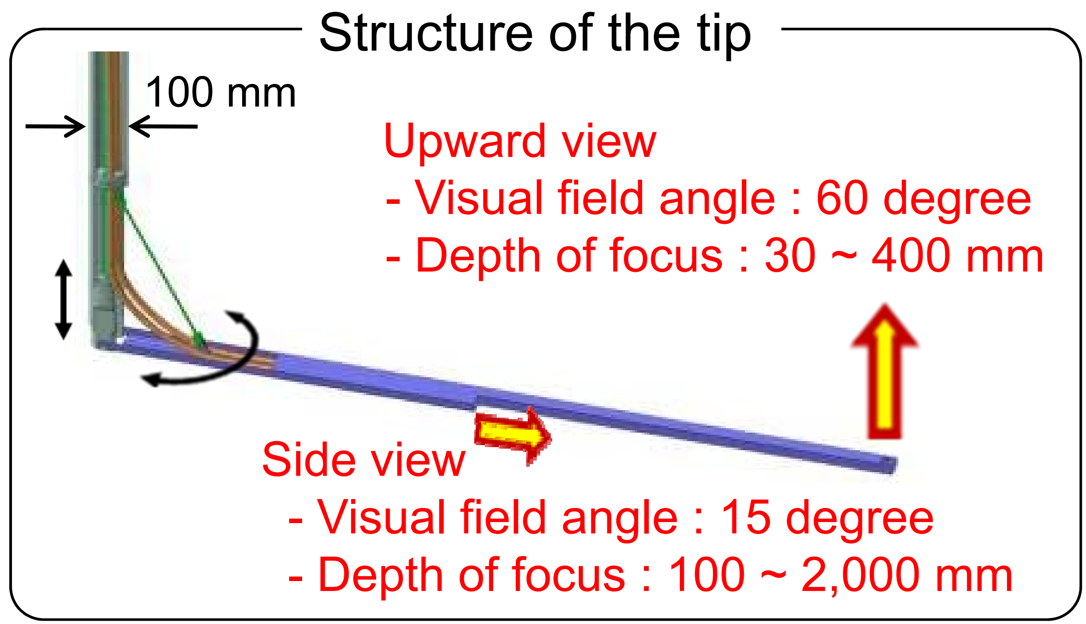


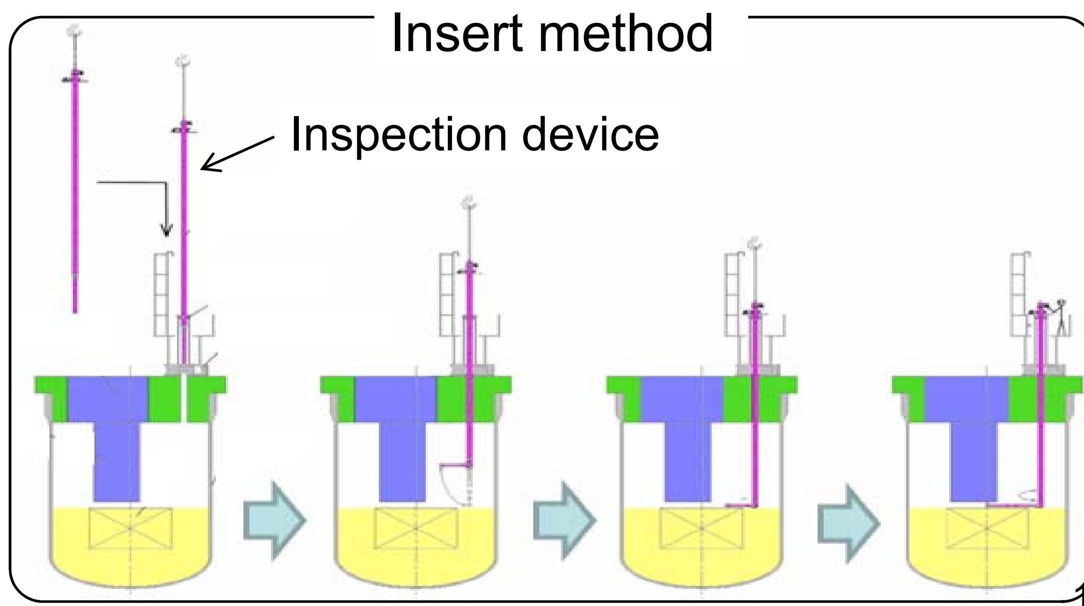


Visual inspection device for UCS bottom

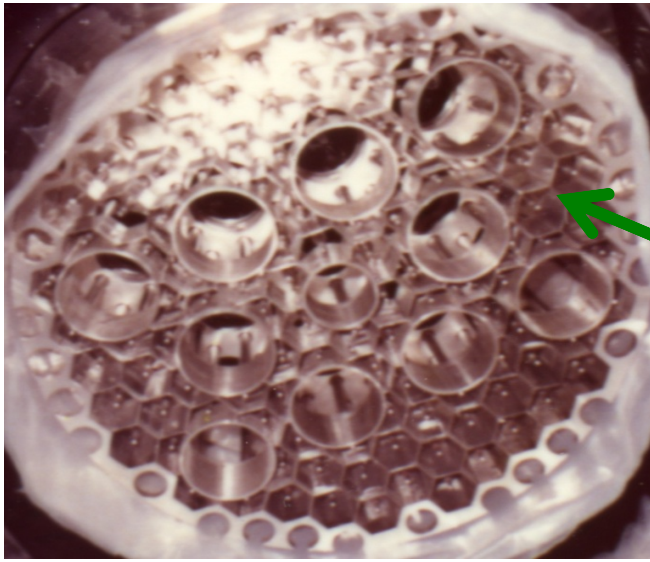




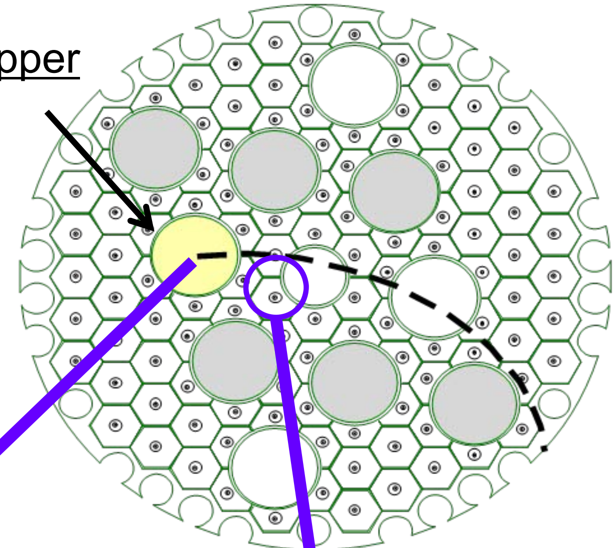


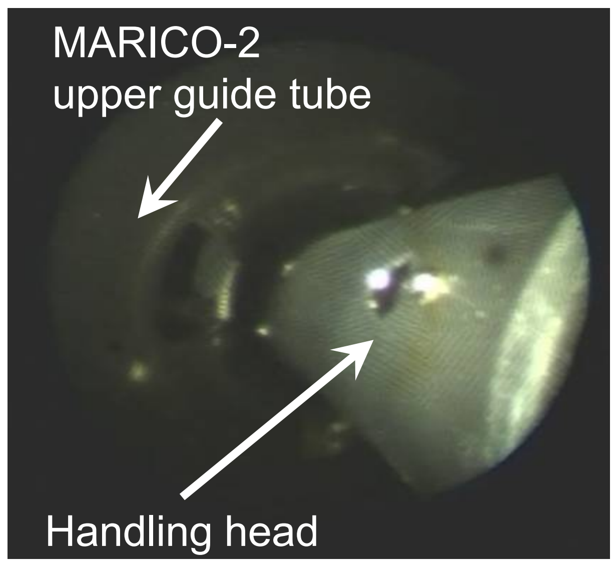


Results of UCS bottom face observation

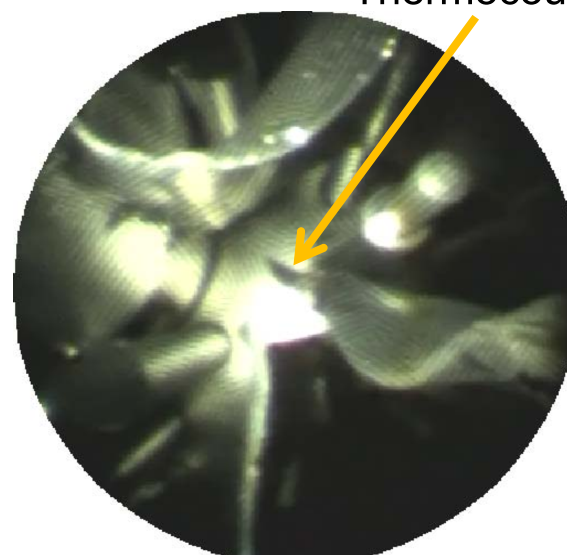


UCS bottom face



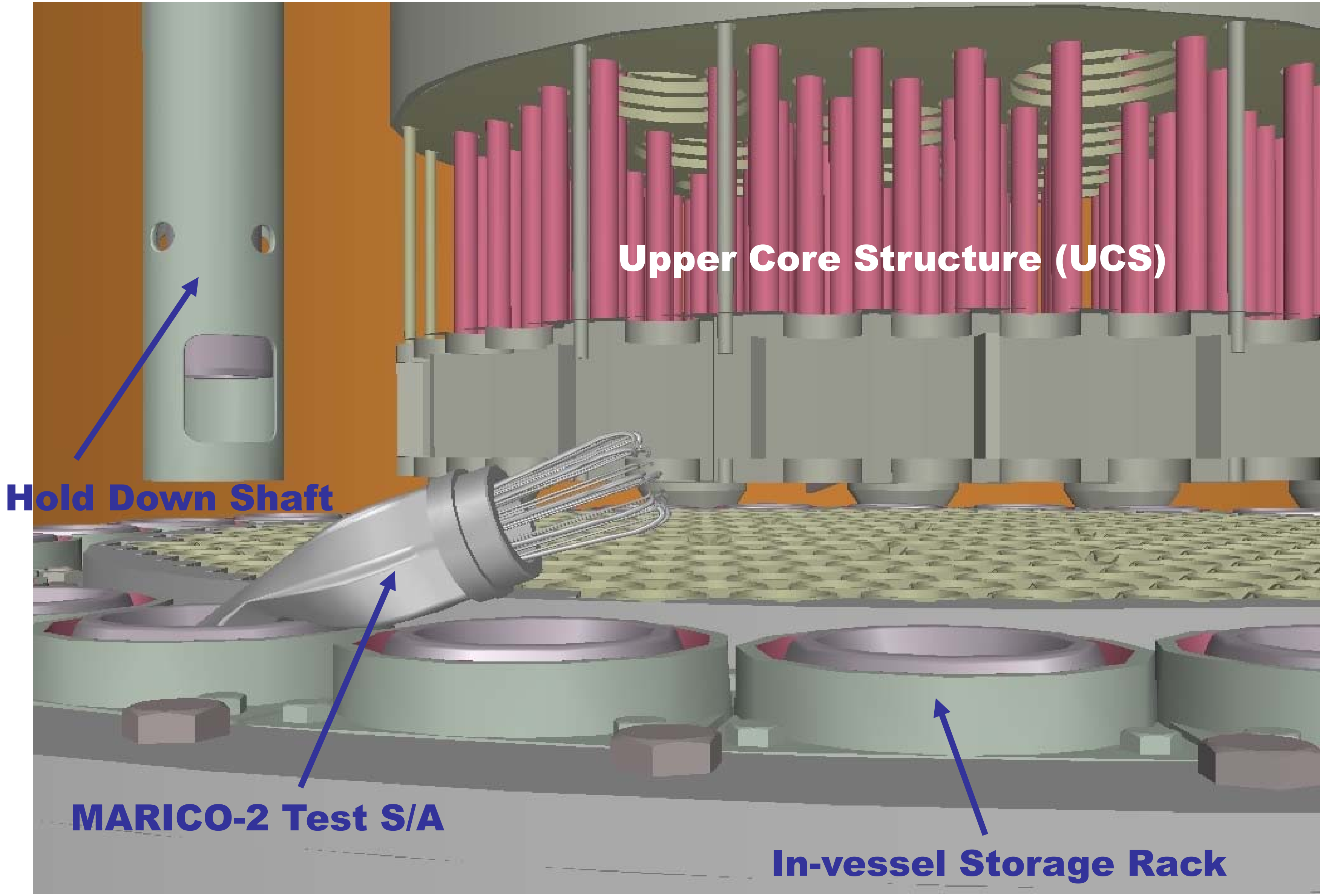


Handling head connected with holding mechanism



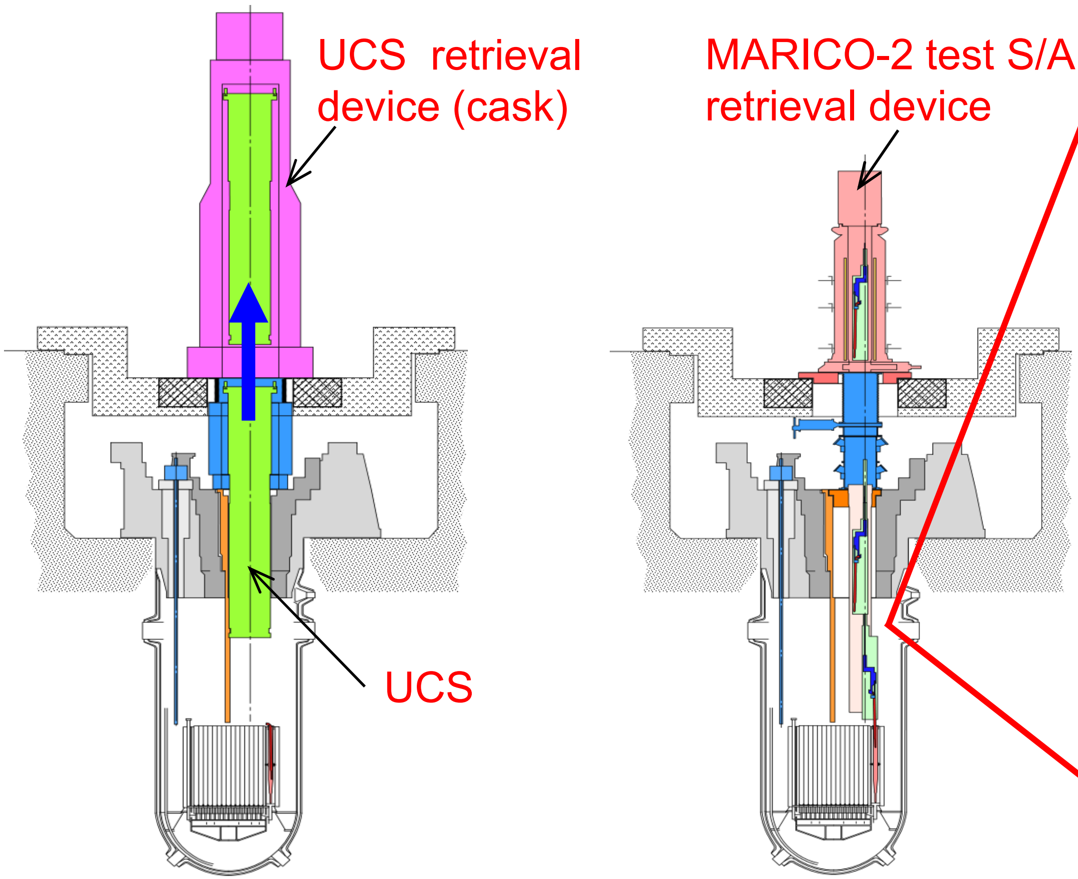
Deformed regulating grid

3-D image of bent MARICO-2 test assembly



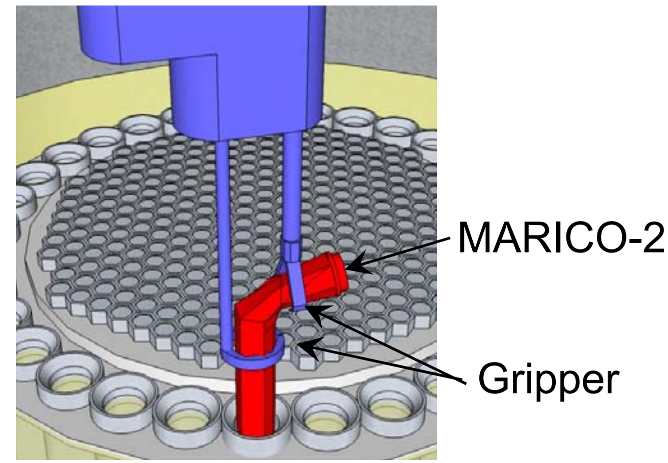
Replace UCS and retrieve MARICO-2 test S/A

1. Remove the existing UCS
2. Retrieve the MARICO-2 through the hole from which UCS is removed
3. Insert new UCS

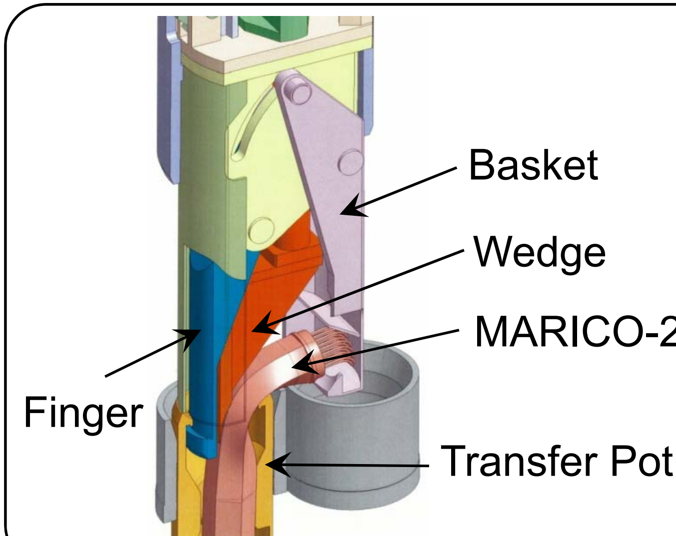


Replace UCS

Retrieve MARICO-2



Grip MARICO-2 wrapper tube



Grip transfer pot

Major subjects of UCS replacement

(1) High radioactivity of UCS
- **UCS cask weight (preliminary evaluation) : >110 ton**
- **Allowable load of C/V crane : 100 ton**

Reducing UCS cask weight

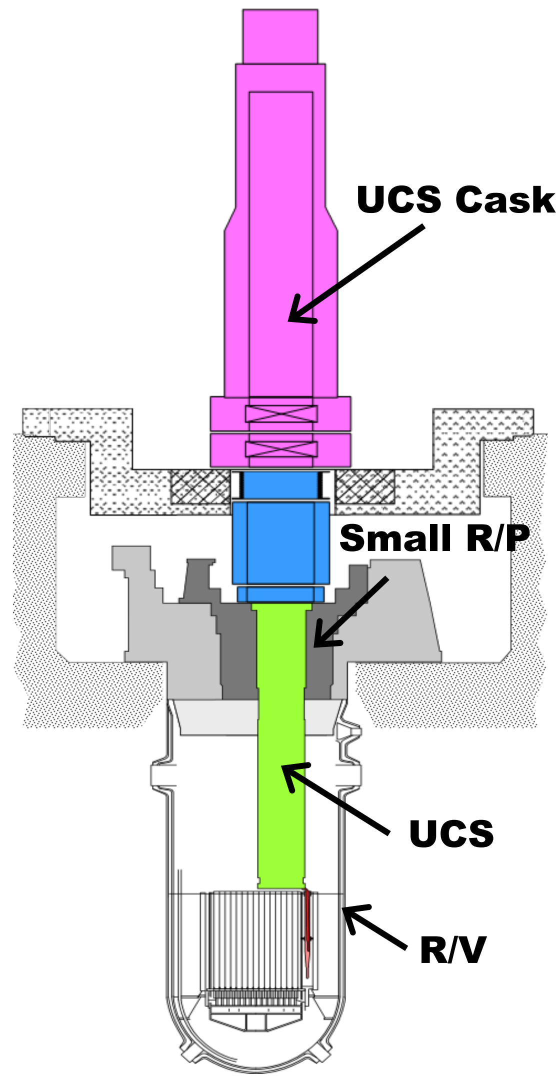
(2) Sodium deposition between UCS and small-R/P
- **Overload during UCS removal**
  → Deformation of UCS and small-R/P

Proper evaluation of sodium deposition

(3) UCS inclination control
- **Minimum gap between UCS and small-R/P : 5 mm**

UCS jack-up device with severe inclination control

(4) Prevent impurity ingress to the sodium system
⇒ **Control of cover gas pressure,**
impurity concentration monitoring etc.
(Experience of cooling system renovation in MK-III modification work)



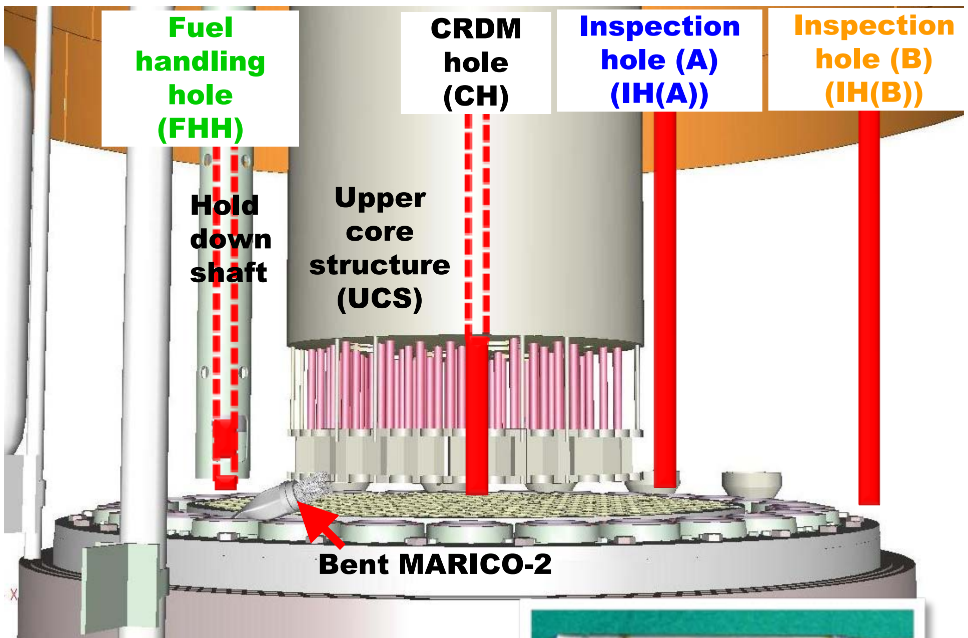
Measure for reducing UCS cask weight

Cask design target

- UCS cask weight : <100 ton (including UCS 16.5 ton)
- Surface dose rate of cask : <1 mSv/h

(1) In-vessel gamma dose measurement

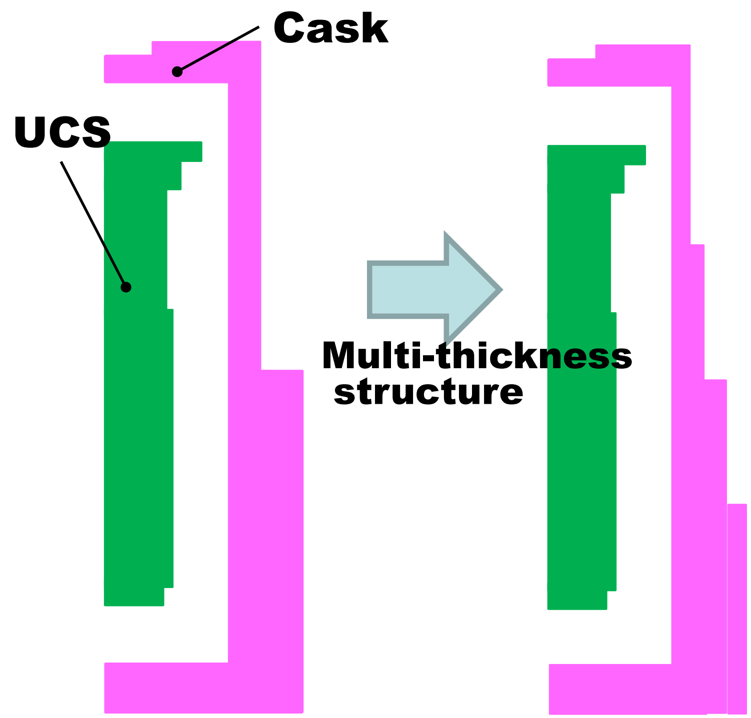
- Optimization of cask thickness based on dose rate distribution of UCS measured value



Detector
Type : Ionization chamber (IC)
Range : 0.1～1000 Gy/h

(2) Optimization of UCS cask structure

- Variations of thickness : 2 → 4
  * From a manufacturing standpoint, two kind of thickness is better.



Dose rate on UCS surface
- Evaluation Method -

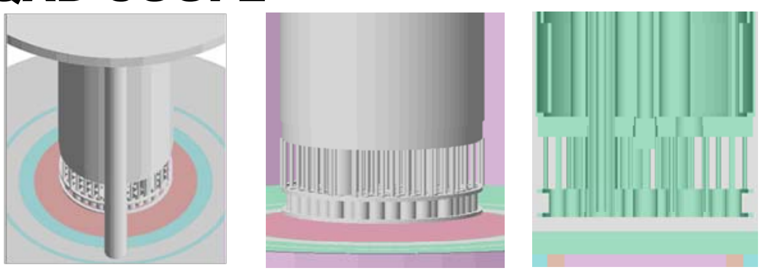
Neutron flux calculation
2-D transport code DORT

↓ **Neutron flux, σ**

Gamma-ray source calculation
ORIGEN2

↓ **Gamma-ray source**

Gamma-ray flux calculation
QAD-CGGP2

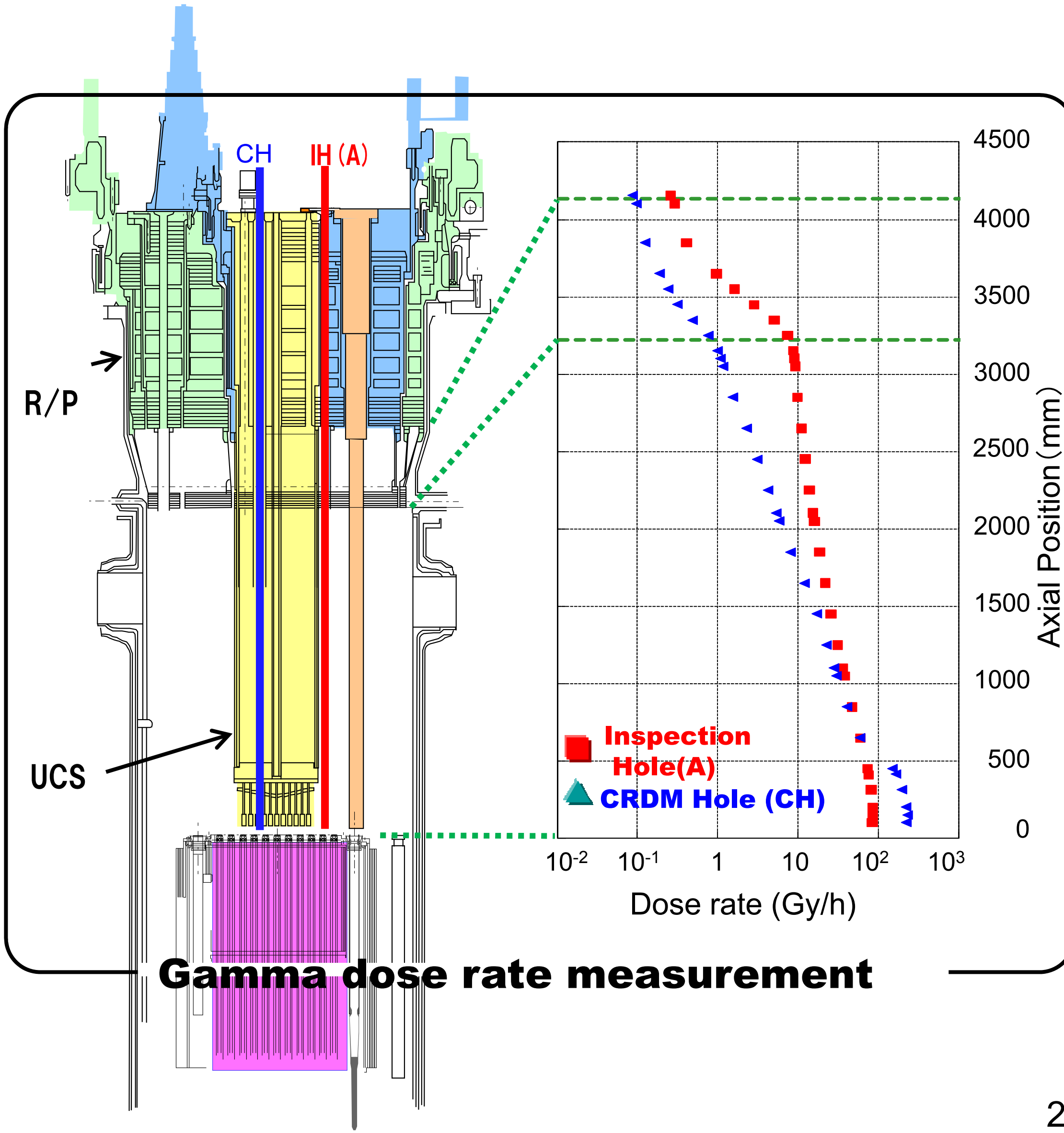


↓ **Conversion to dose : ICRP74**

Calculated gamma dose rate

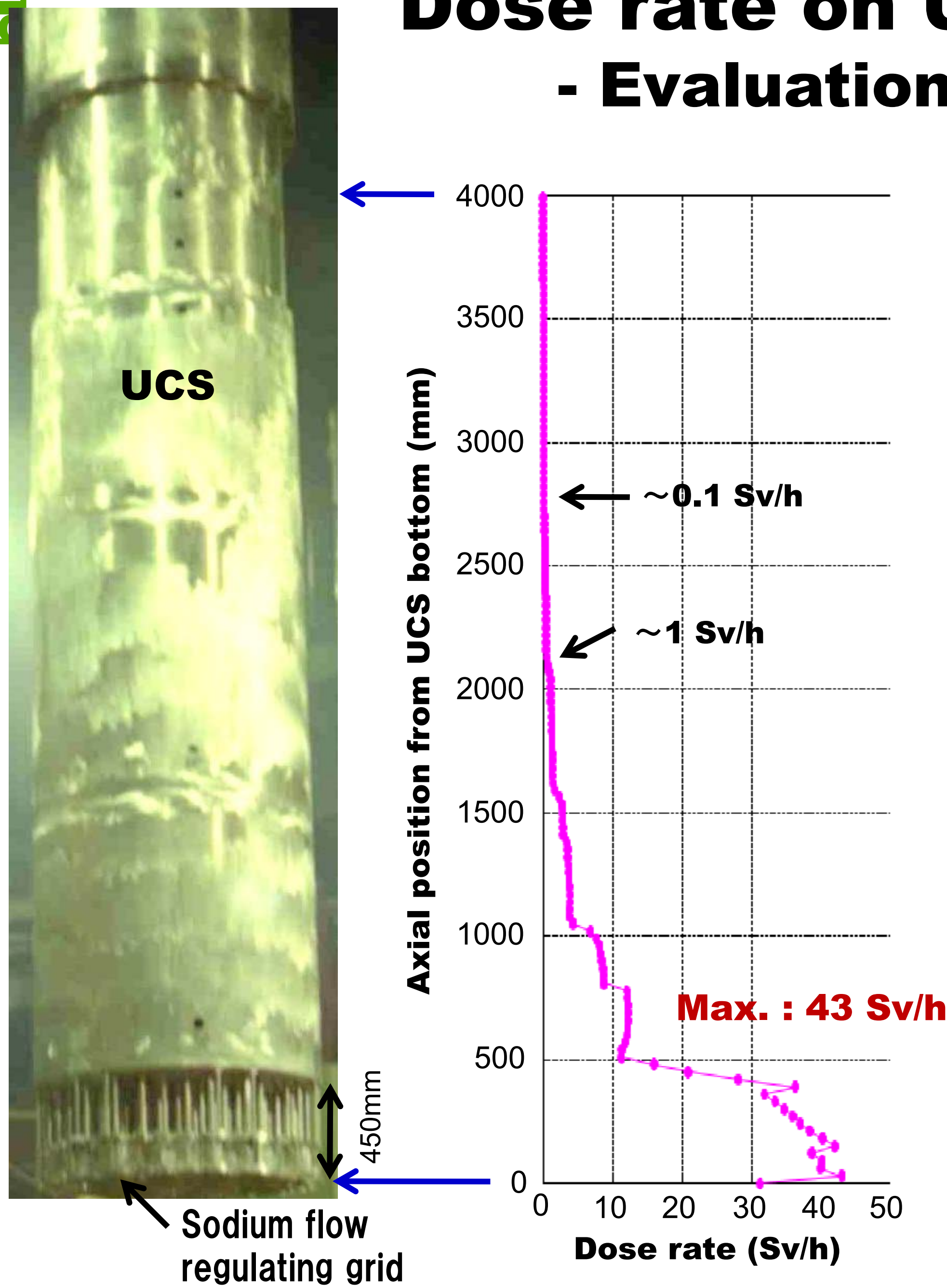
↓ **Corrected by measured value**

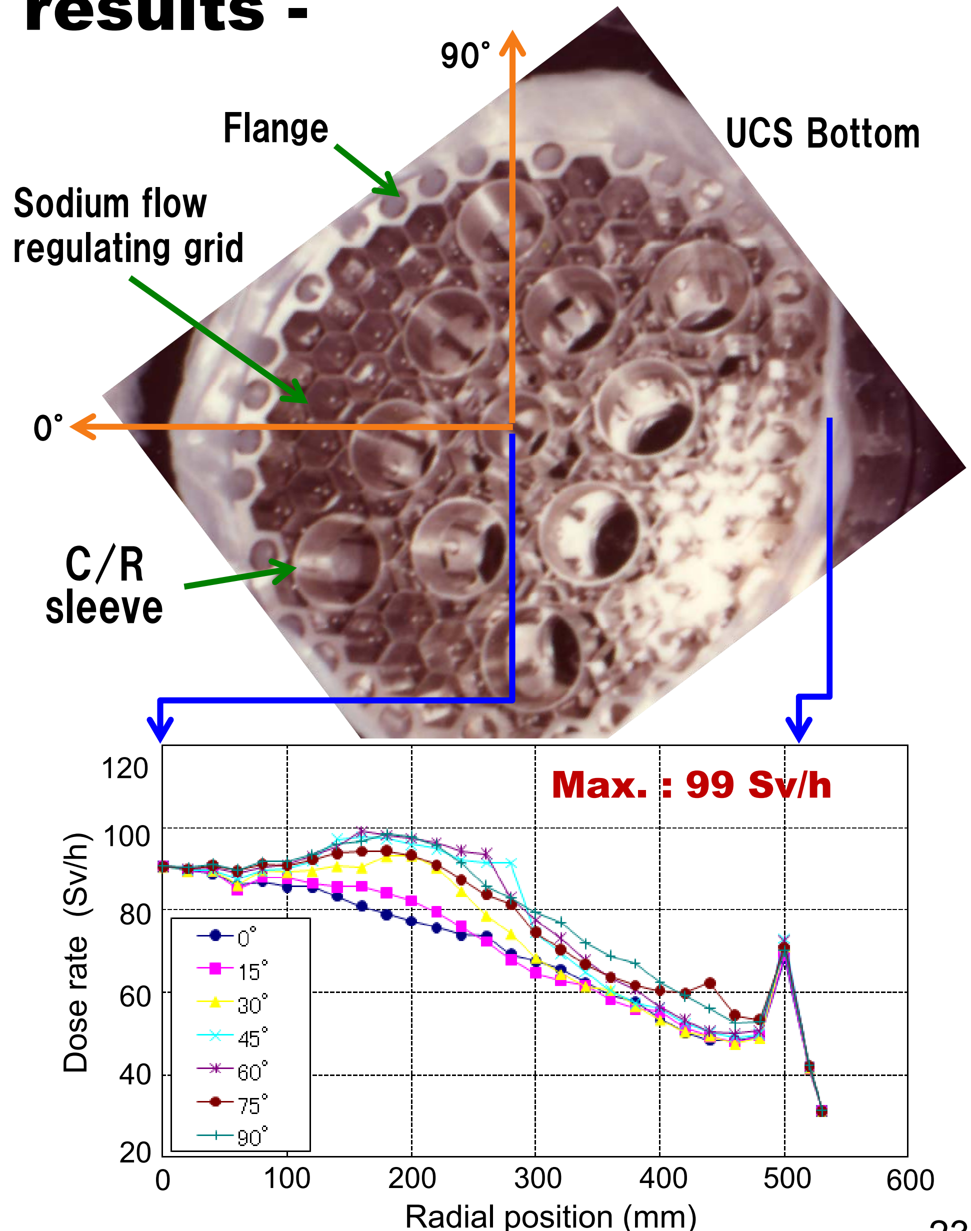
Dose rate distribution on UCS



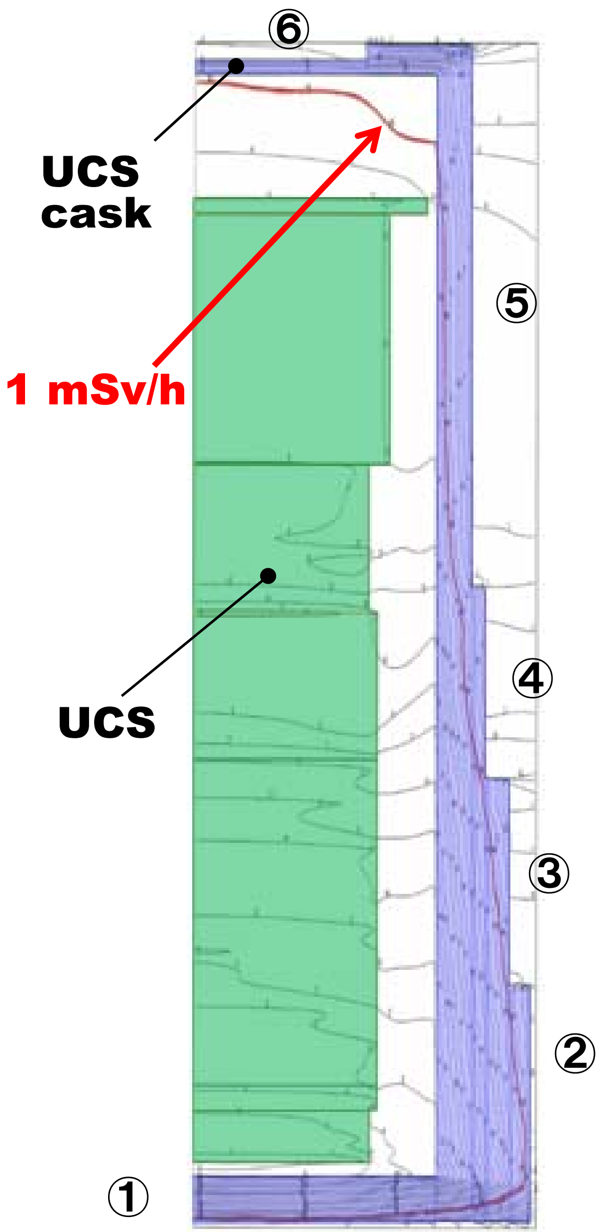
Gamma dose rate measurement

Dose rate on UCS surface
- Evaluation results -





Shielding design result of UCS cask



Position		Thickness (cm) (Carbon steel)	Dose rate on cask surface (μSv/h)
Top ⑥		10	<50*
Side	⑤	10	132
	④	14	525
	③	21	627
	②	27	564
Bottom ①		29	896

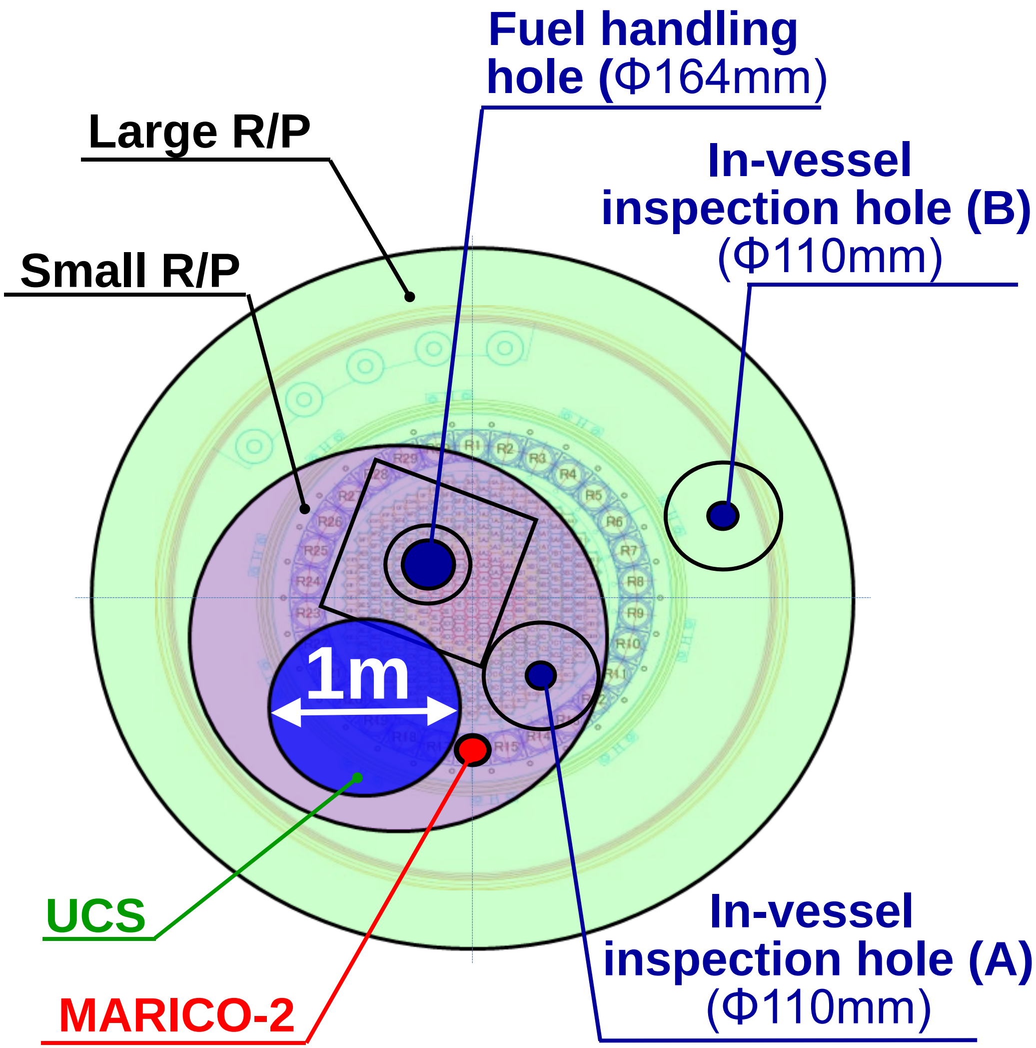
* : The top of the cask (⑥) satisfies allowable dose rate (1mSv/h) with 0mm in thickness. Taking account of cask strength, ⑥ has same thickness as ⑤.

Total weight of UCS cask : ~93.4ton (with UCS (16.5 ton))

below allowable load of crane (100ton)

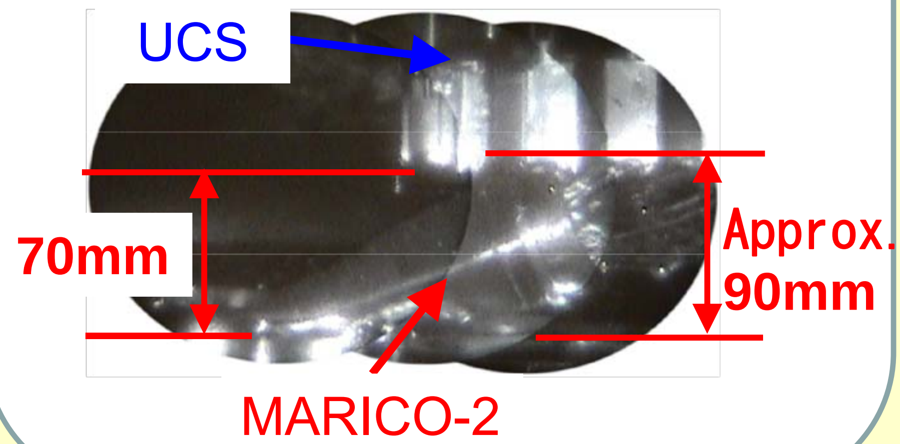
Retrieval procedure of bent MARICO-2

Access route



Geometric condition

UCS can not be positioned right above the bent MARICO-2 to avoid a contact with it.



⇩

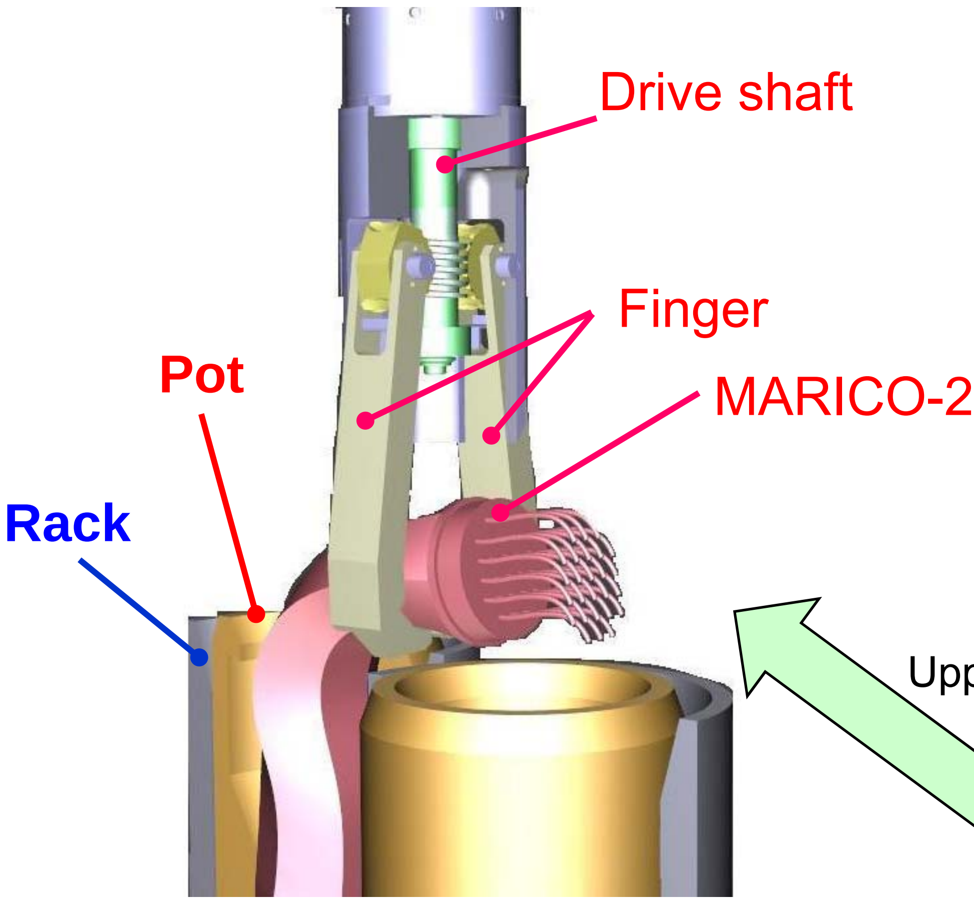
The retrieval device employs *"offset configuration"*

Lifting-up test device of bent MARICO-2 (1)

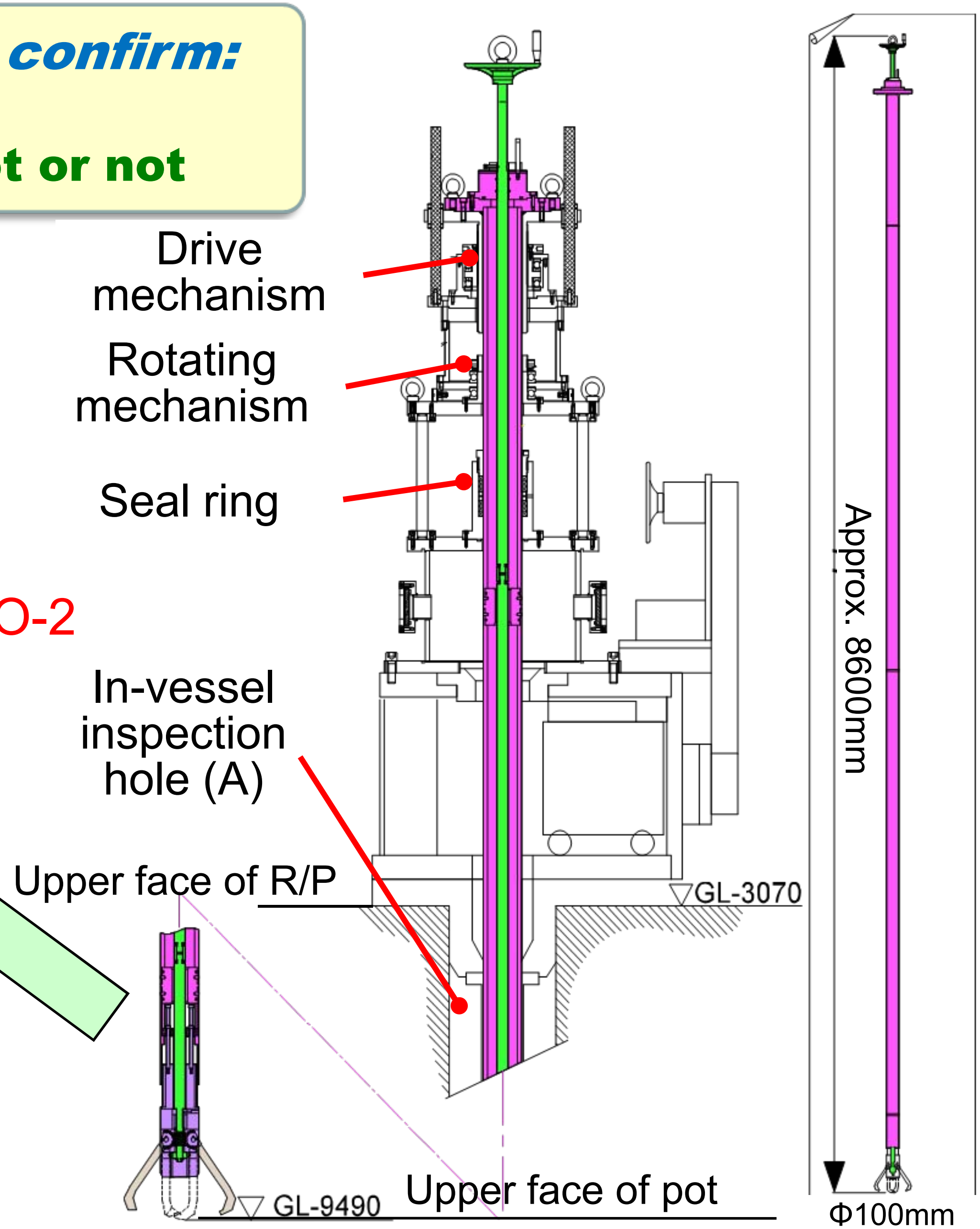
Lifting-up test was planned to confirm:

- bent MARICO-2 can be lifted-up

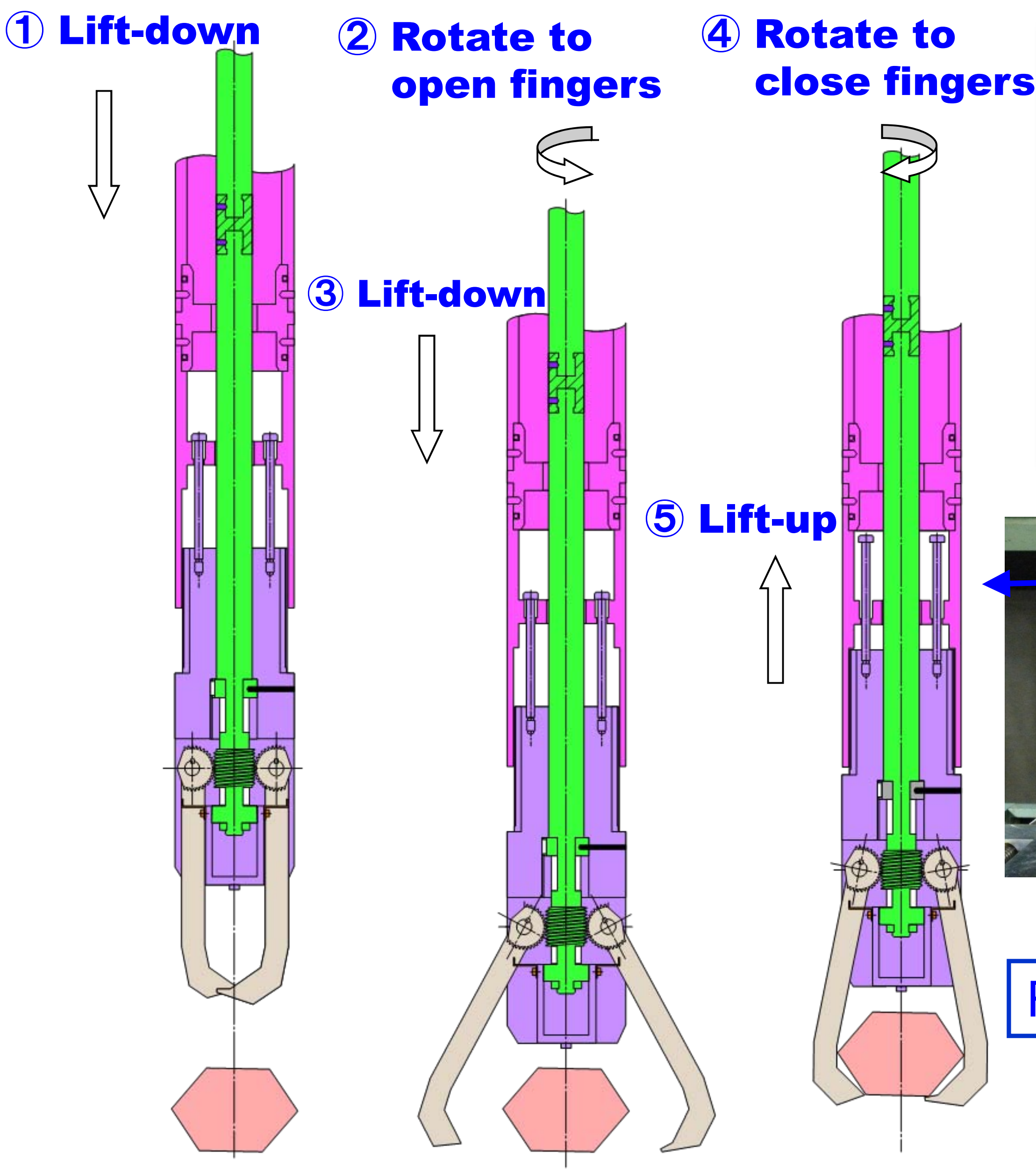
- stuck of bent MARICO-2 with pot or not



Lifting-up test device

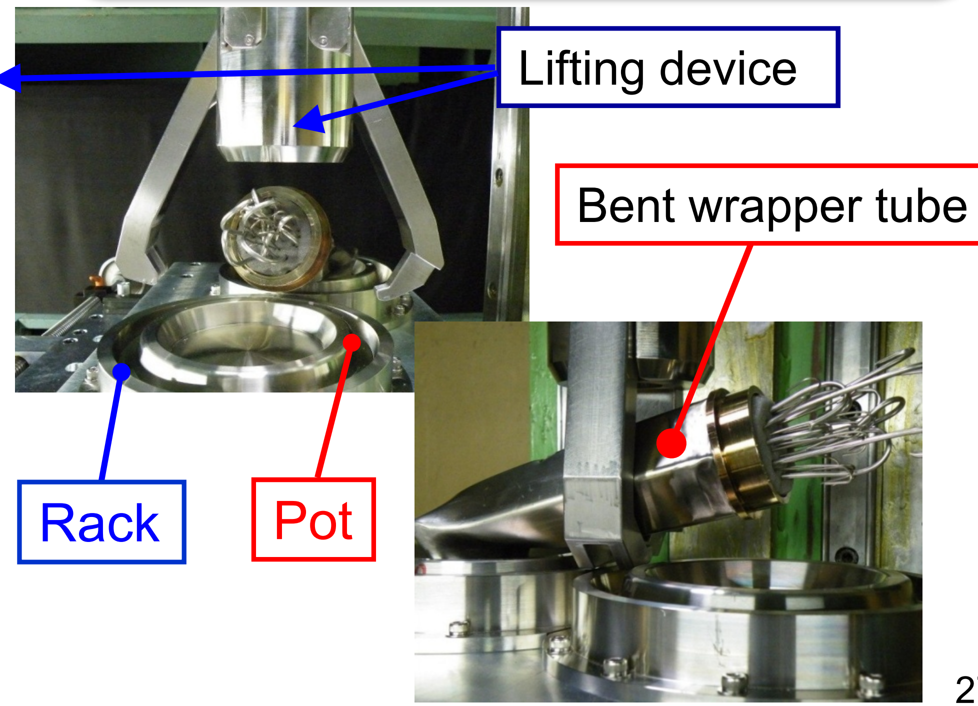


Lifting-up test device of bent MARICO-2 (2)



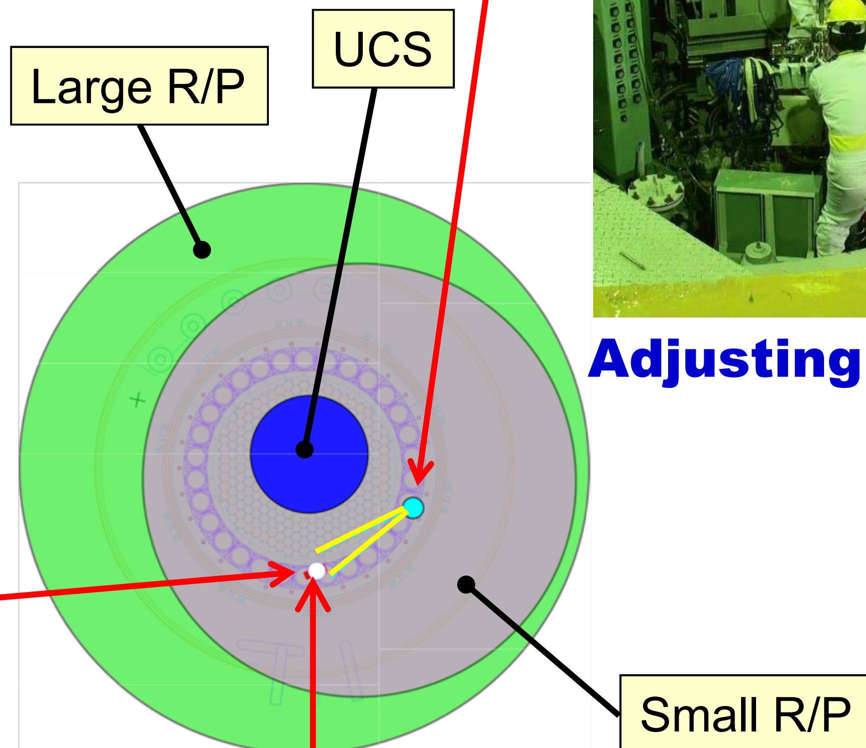
Lifting-up simulation test was conducted to confirm :

- **Holding function of bent part of wrapper tube**
- **Adjustment against position difference etc.**
- **Visual condition by optical fiber**



Lifting-up test

Fiberscope
(Fuel handling hole)



Adjusting angle of fingers

Lifting-up device
(In-vessel inspection hole (A))

Insertion of device

MARICO-2

Lifting-up test of bent MARICO-2

Nov. 18th 11 : 00

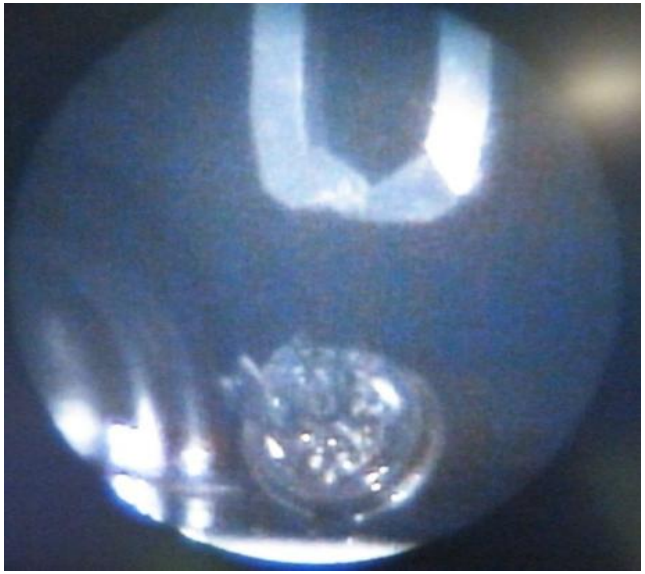
Insertion of fingers

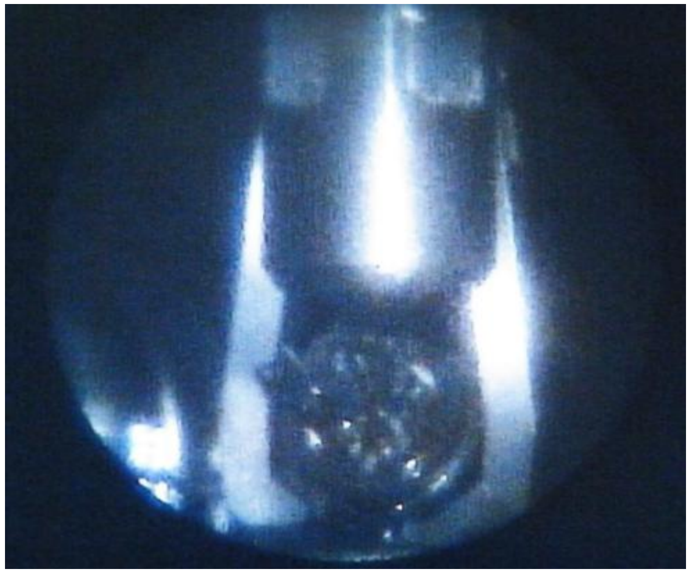
12 : 47

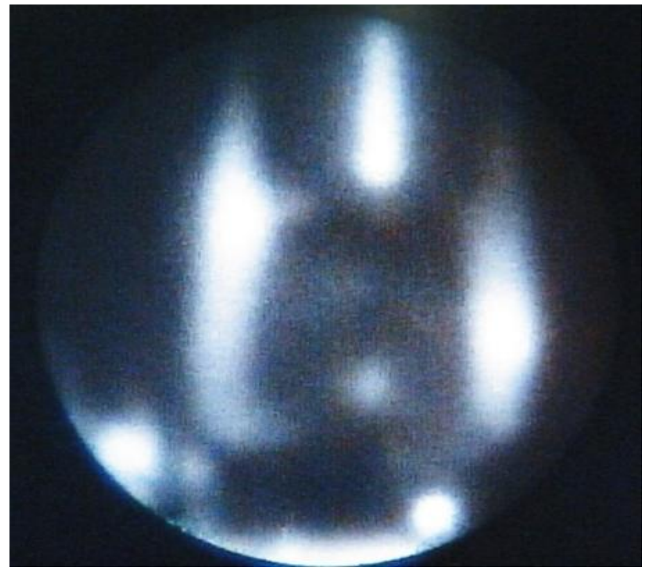
Finger position adjustment

14 : 15

Bent MARICO-2 lifting-up

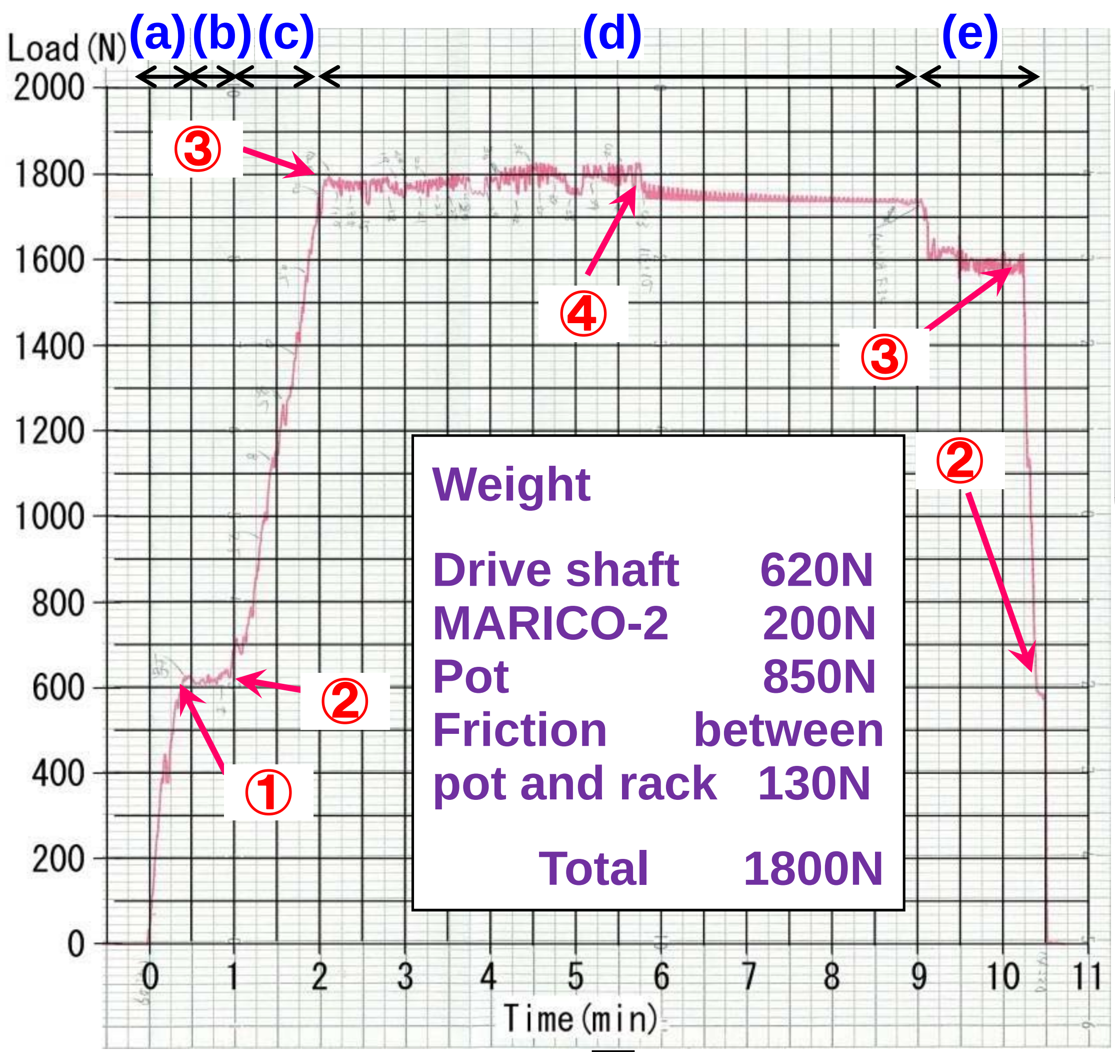






The picture was obtained by fiberscope during lifting-up operation.

Measured load during lifting-up test



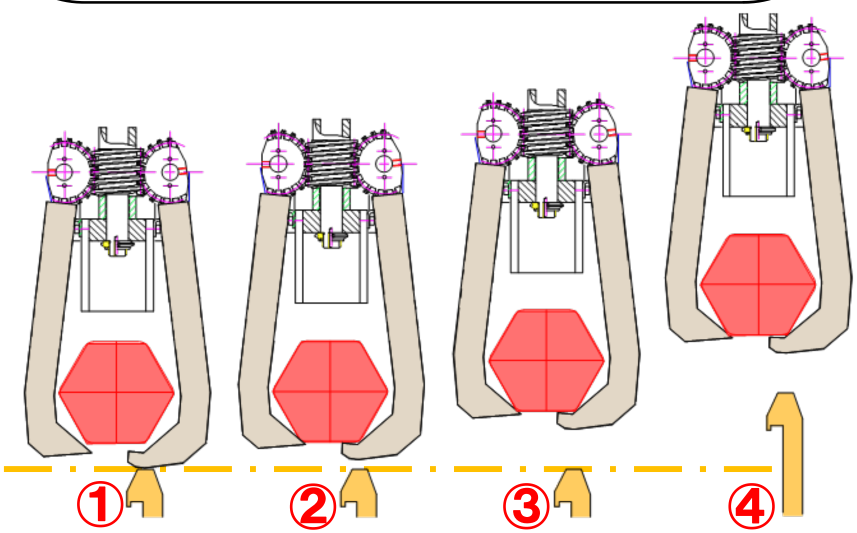
(a) Increasing load for lifting-up drive shaft (0mm)

(b) Lifting-up drive shaft only (0-5.5mm)

(c) Increasing load for lifting-up MARICO-2 with pot (5.5-10.5mm)

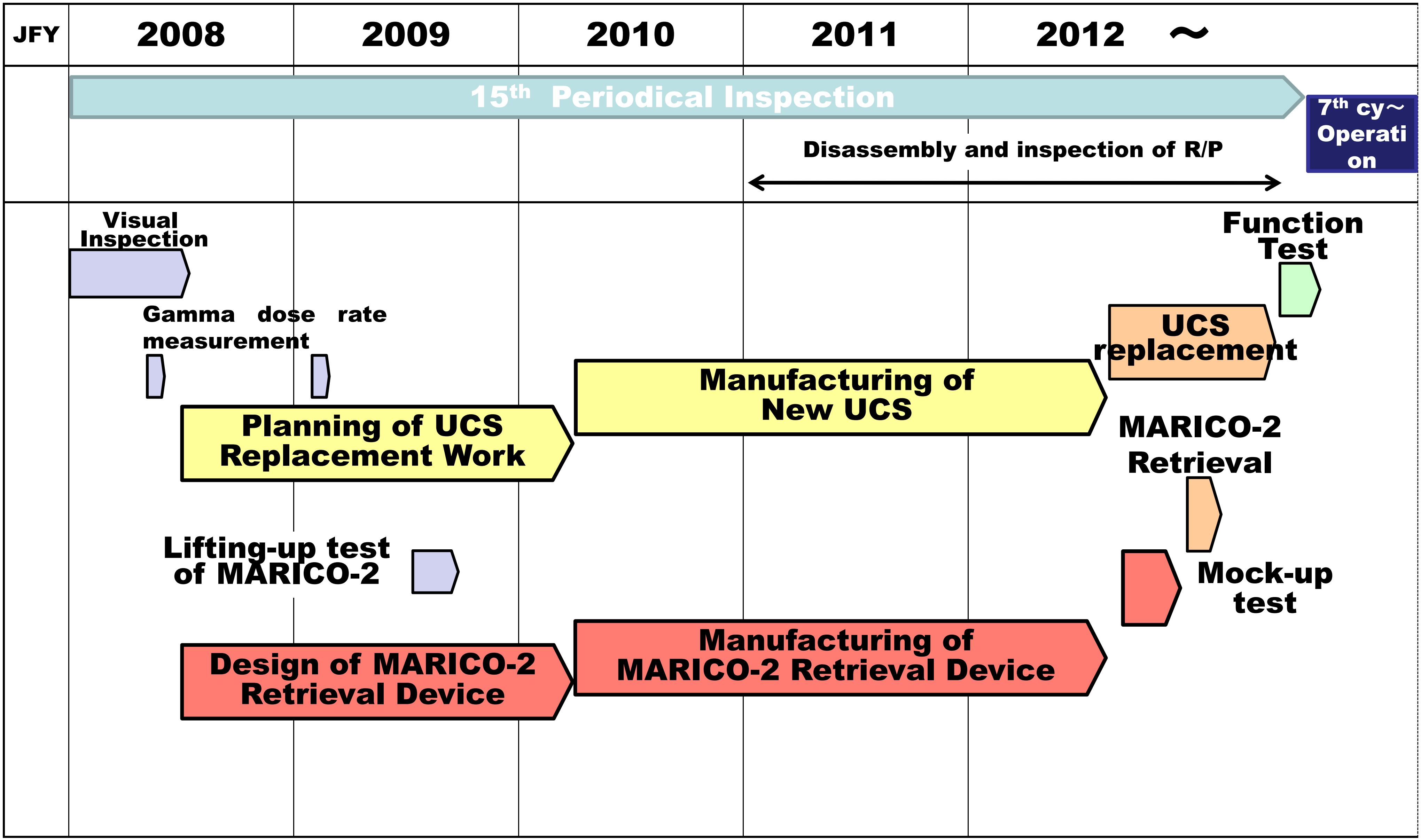
(d) Lifting-up MARICO-2 with pot (10.5-43mm)

(e) Lifting down

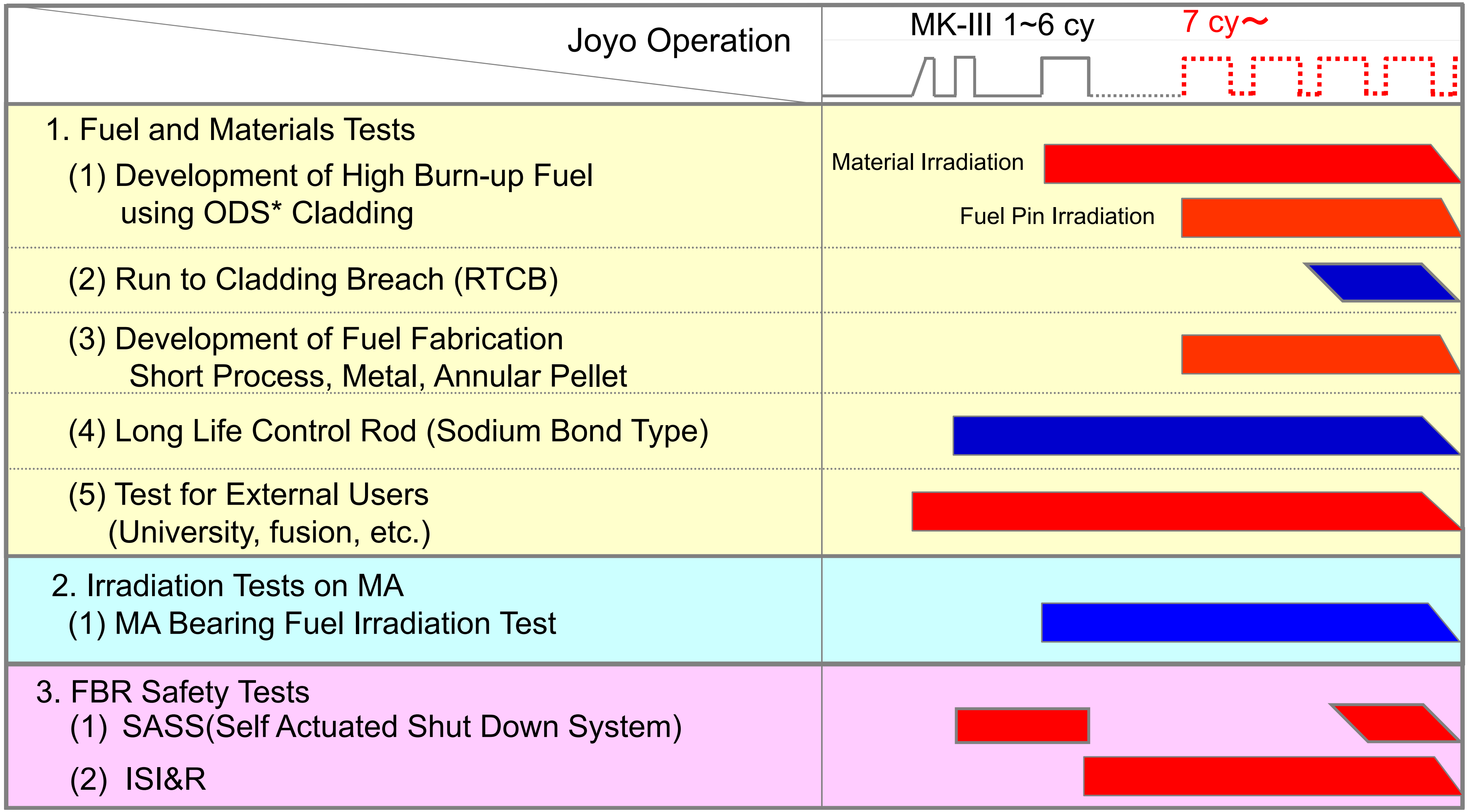


This result indicated that bent MARICO-2 was lifted-up together with pot, but the rack was not stuck with pot.

Master Schedule for Joyo Resumption



Joyo's Roles for FBR Fuel Cycle Development



* ODS: Oxide Dispersion Strengthened Ferritic Steel

Summary

- In-vessel visual inspections were successfully conducted by fiberscope and video camera.
  These results are reflected to the restoration work of Joyo.

- The design of retrieval device of damaged UCS and bent MARICO-2 has been almost finished based on the radioactivity evaluation of UCS and lifting test of bent MARICO-2.

- Valuable experience and data are obtained through restoration work.