Fuel removal from the spent fuel pool at Fukushima Daiichi Nuclear Power Station Unit 3

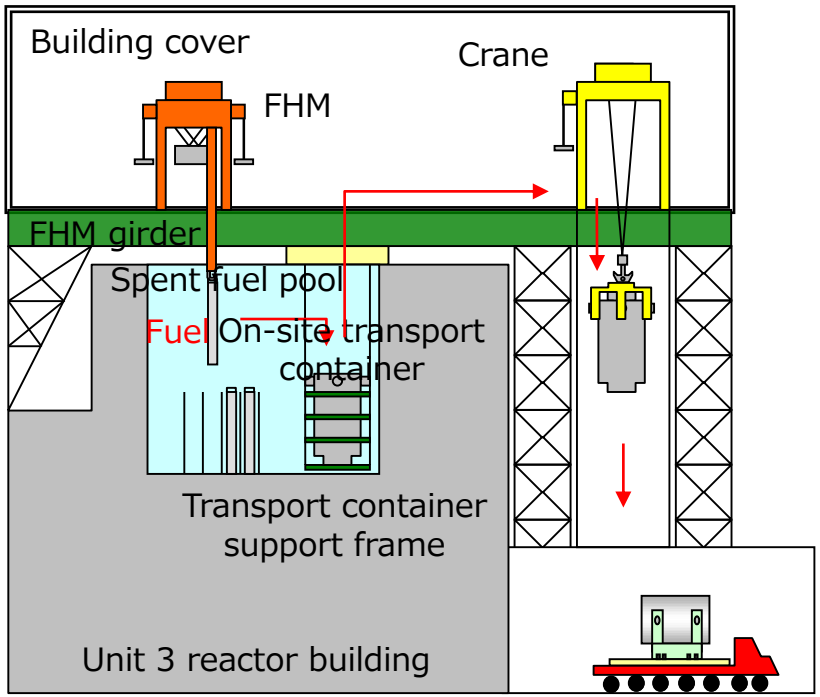
July 26, 2018

Tokyo Electric Power Company Holdings, Inc.
Fukushima Daiichi D&D Engineering Company

1. Outline of fuel removal from Unit 3 spent fuel pool (1/2)

- 514 assemblies for spent fuel and 52 assemblies for unused fuel (total: 566 assemblies) are stored in the Unit 3 spent fuel pool.
- Fuel will be put into an on-site transport container using remotely operated equipment after removing small rubble over the fuel, and then transported to the common pool located on-site.

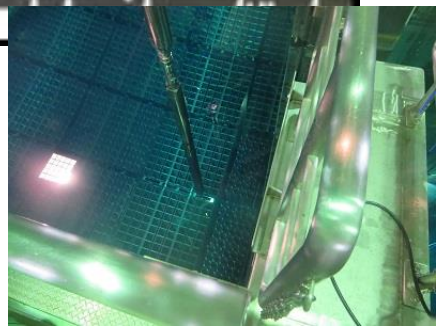
Unit 3 reactor building



Transportation on-site

Common pool

Stored in the fuel rack



Photos taken on Nov. 22, 2013

1. Outline of fuel removal from the Unit 3 spent fuel pool (2/2)

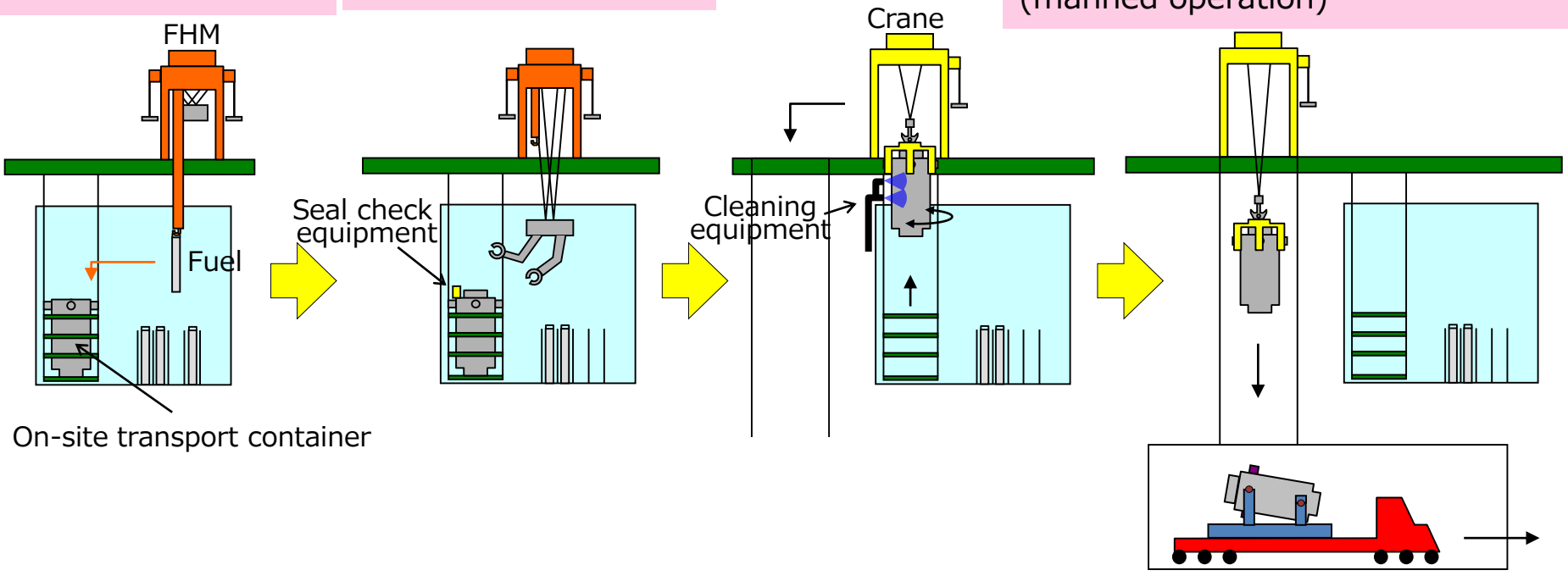
- The fuel handling machine (FHM) grabs the fuel assemblies one by one to put them into the on-site transport containers.
- The on-site transportation container is lowered to the ground floor and a secondary lid is attached.
- The container is loaded onto a transport vehicle and transported to the common pool.

Fuel picked up from the rack and put into an on-site transport container

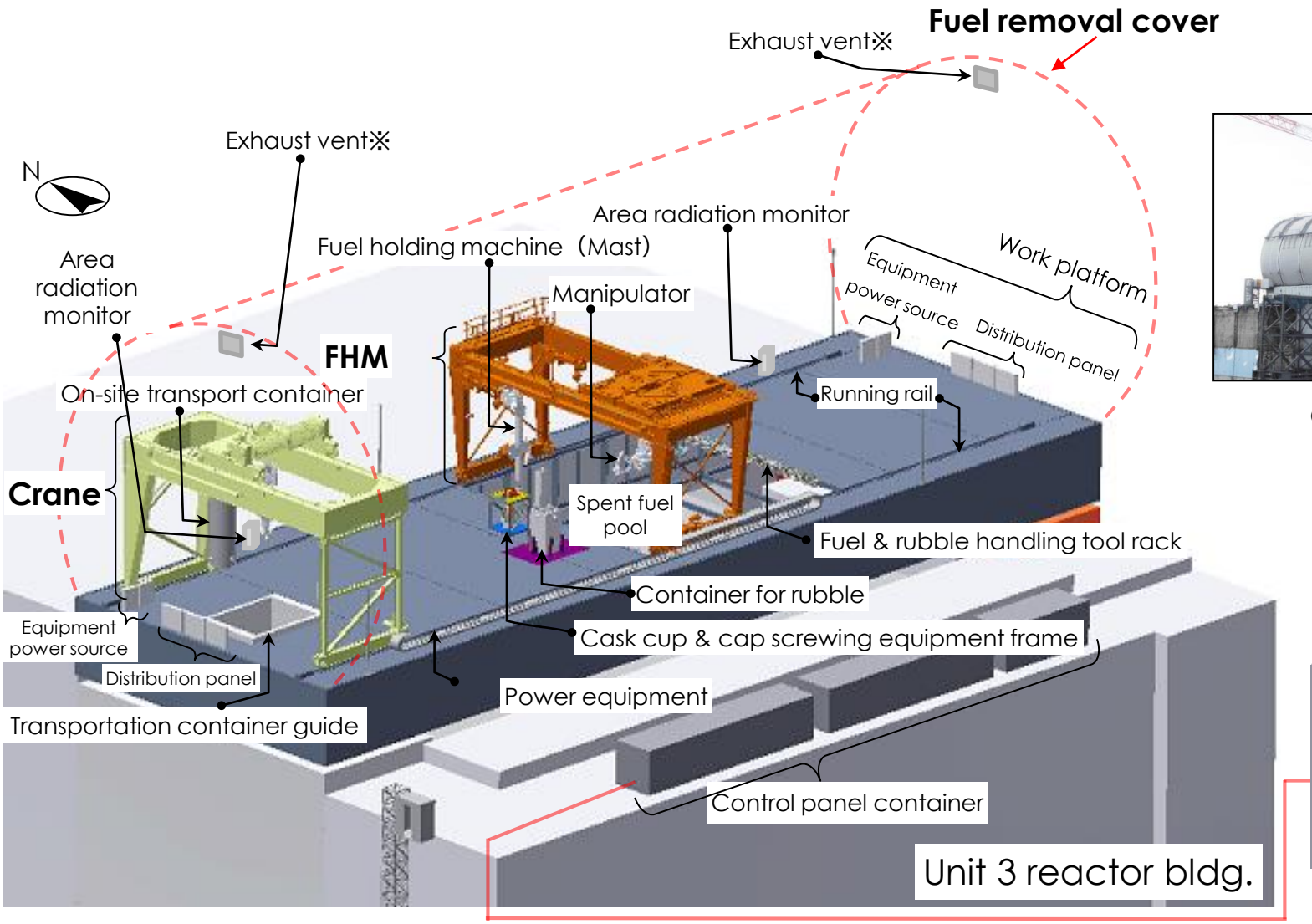
Primary lid attached to the on-site transport container and seal checked

Surface of the container is cleaned and dried

Container is lowered down to the ground floor, a secondary lid is attached and the container is transported to the common pool (manned operation)



2. Outline of fuel removal cover and fuel handling machine



Outside Unit 3

Remote operations room (Main Office Bldg.)

※Concentration of radioactive material in the dust inside the cover is measured by sampling air from exhaust duct.

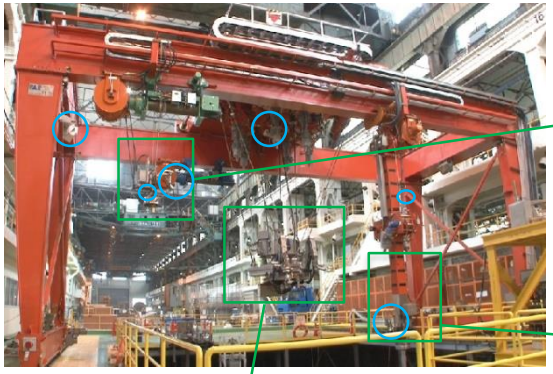
2-1. Fuel handling machine and crane

■ Fuel handling machine

- Removes rubble using various tools attached to manipulators or auxiliary hoists.
- Grabs handle of fuel assembly, extracts it from the fuel rack and puts it into an on-site transport container in the pool.

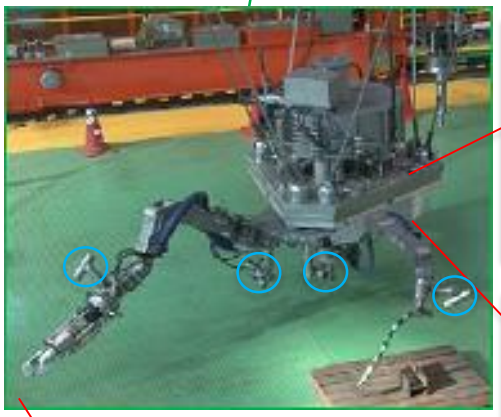
■ Crane

- Tightens the lid of the on-site transportation container containing fuel and lifts it out of the spent fuel pool to the ground floor.



Hook-shaped tool attached to the end of the auxiliary hoist is used to hang a basket into which rubble grasped by manipulator is collected.

Fuel grasping machine grasps the handle of a fuel assembly and moves it. Handles found to date that are bent can also be grasped.



Two manipulators attached to tensile truss can grasp and cut rubble. Each joint angle can be maintained by its structure even if hydraulic control is lost.

Manipulators are used as supports when removing rubble and fuel from the pool.

Tools attached to the end of the manipulator can be replaced remotely. Tools for gripping and cutting are prepared.

Gripper

Cutter

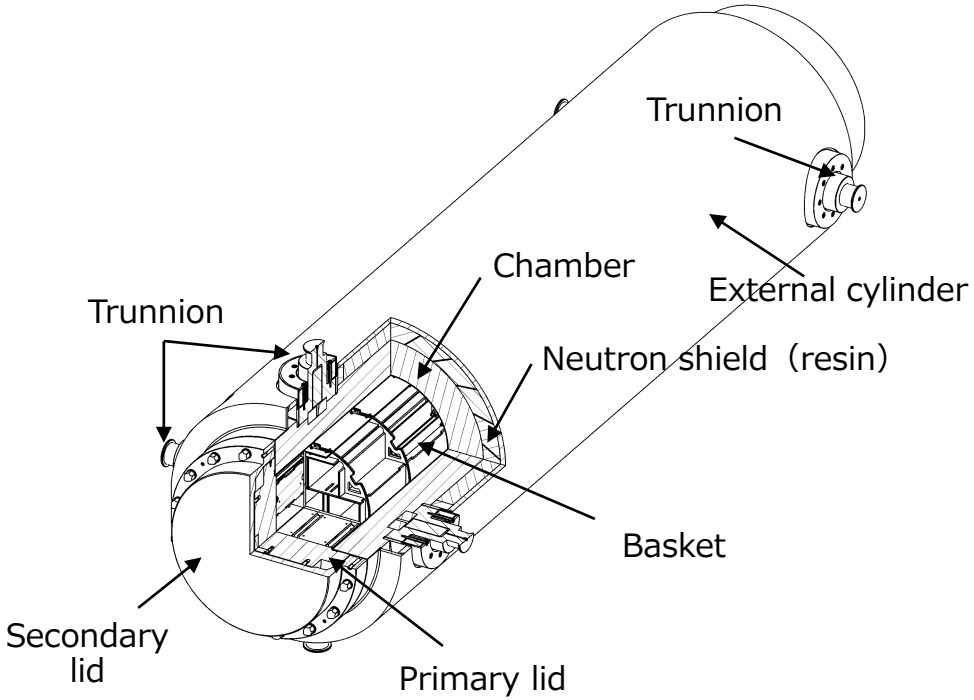
○ : Camera position

Vertical hoisting attachment on the main winch hook hoists the on-site transport container.

The lids of the on-site transport containers are screwed on using tightening equipment attached to the end of the auxiliary winch.

2-2. Outline of the on-site transport container

- An on-site transport container capable of storing seven fuel assemblies was newly developed so that the Unit 3 crane with a rated capacity of 50t can handle them and lids can be attached using remotely operated equipment.
- Safety functions equal the NFT-22B type transport container used for Unit 4, and a usage permit received.
- Two containers will be alternately used when transporting fuel from Unit 3 to the common pool for efficiency.



Weight (with fuel)	Approx. 46.3 t
Overall length	Approx. 5.6 m
Outside diameter	Approx. 1.4 m
Storage capacity	7 fuels or less

2-3. Comparison between Unit 3 and Unit 4 (1/2)
Fuel Handling Equipment

TEPCO

Unit 3

FHM

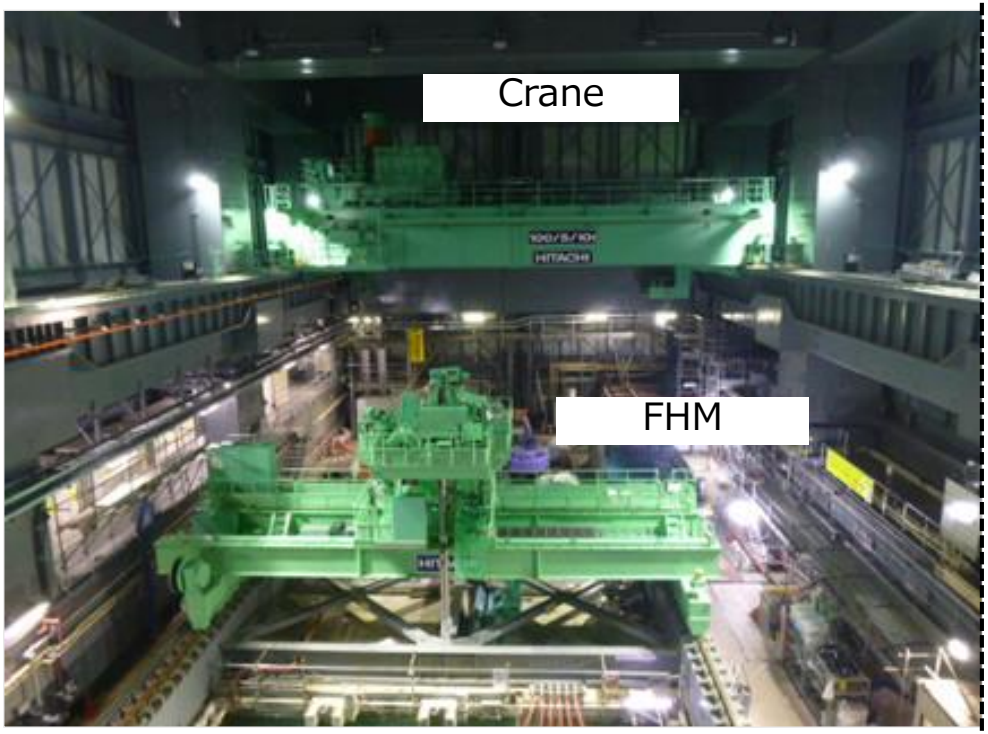
Crane

All operations are remotely controlled.

Unit 4

Crane

FHM



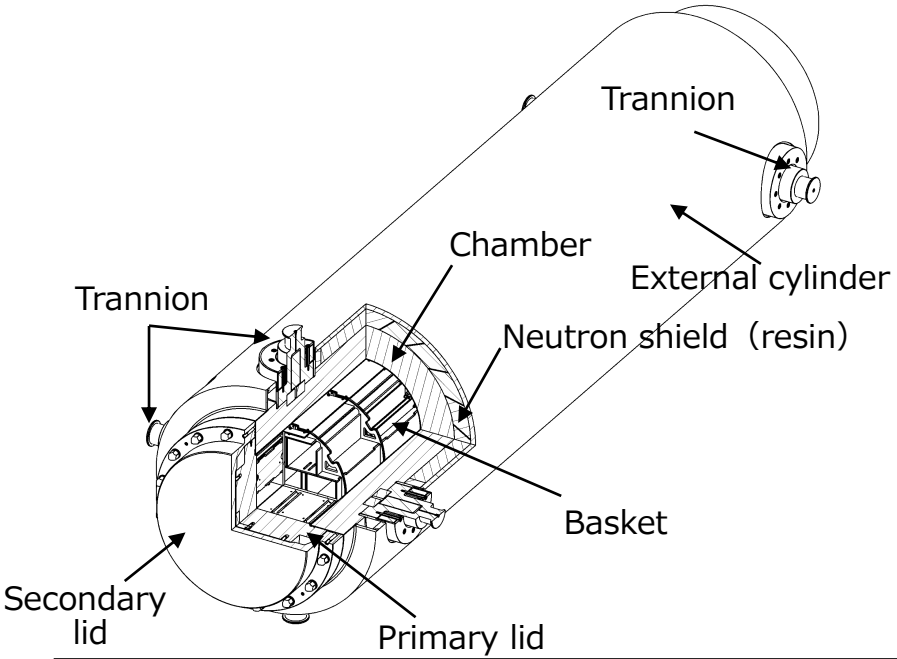
Controlled using controls located on the machine

- Drop-prevention function for fuel and on-site transport container is the same as for Unit 3 and Unit 4.

2-3. Comparison between Unit3 and Unit4 (2/2)
On-site Transfer Container

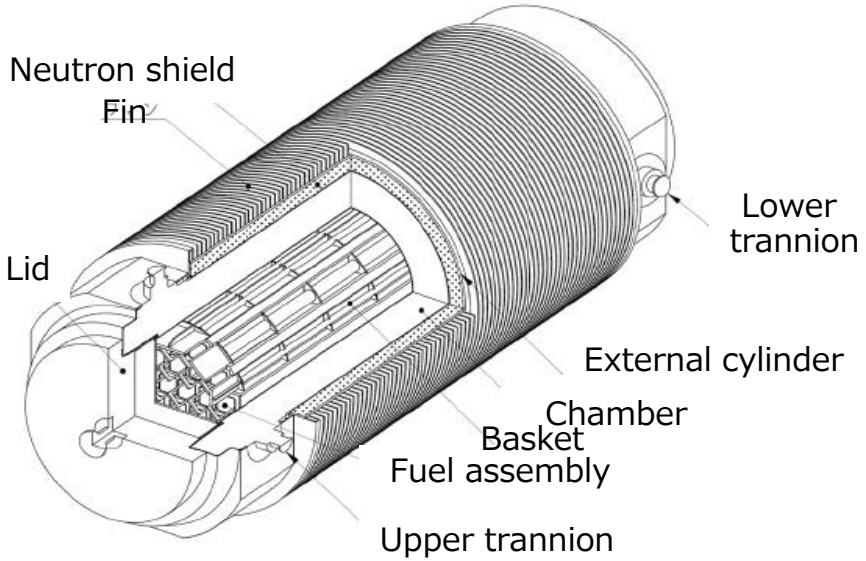
TEPCO

Unit 3



Storage capacity : 7 fuel assemblies
Gross weight : Approx. 46.3 t
Overall length : Approx. 5.6 m
Outside diameter : Approx. 1.4 m

Unit 4



Storage capacity : 22 fuel assemblies
Gross weight : Approx. 91 t
Overall length : Approx. 5.5 m
Outside diameter : Approx. 2.1 m

- Lids for Unit 3 on-site transport container can be screwed on using remotely operated equipment. At Unit 4 such operation needs to be controlled from a short distance.

3. Fuel removal in the future

Small rubble removal from the pool

- Small rubble from the building explosion that now covers the fuel will be removed using manipulators and other tools.
- During fuel removal, small rubble will be removed at night and the fuel removed in the daytime.

Training with the actual equipment

- Operators will be trained on the process of using the fuel handling machine and inserting fuel into transport containers in order to improve skill

Fuel removal

- Removal will start with low risk fuel in order to gain experience.
  - ① Unused fuel not deformed by rubble impact
  - ② Spent fuel not deformed by rubble impact
  - ③ Spent fuel damaged before the accident and fuel deformed by rubble impact

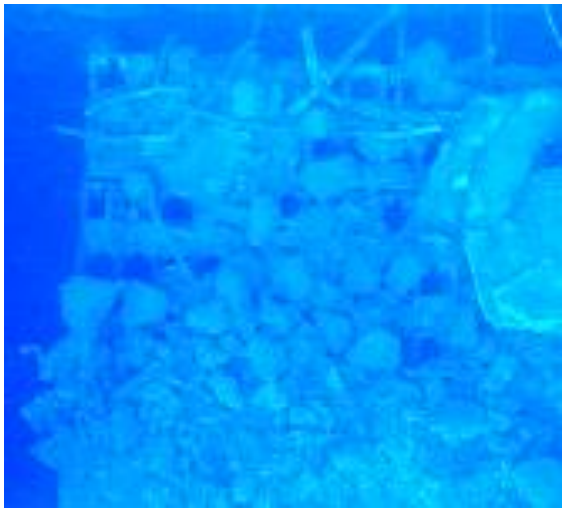
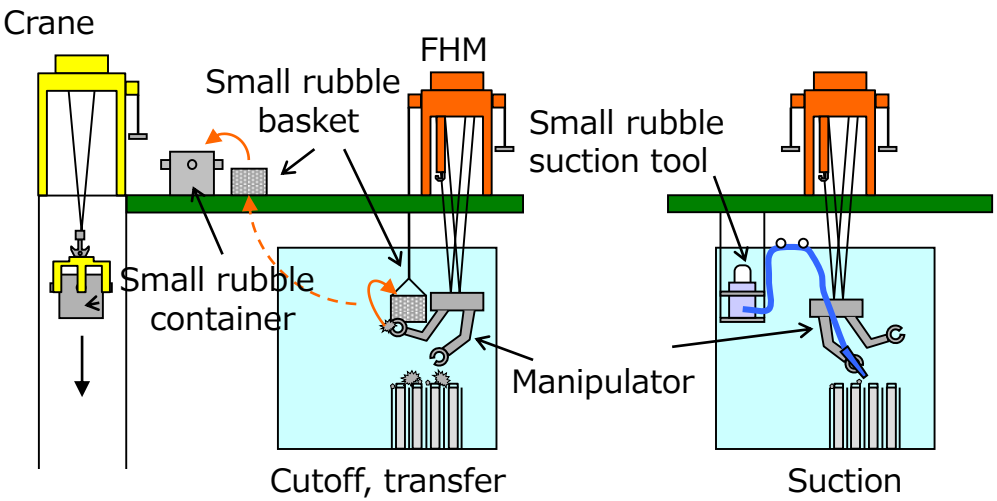


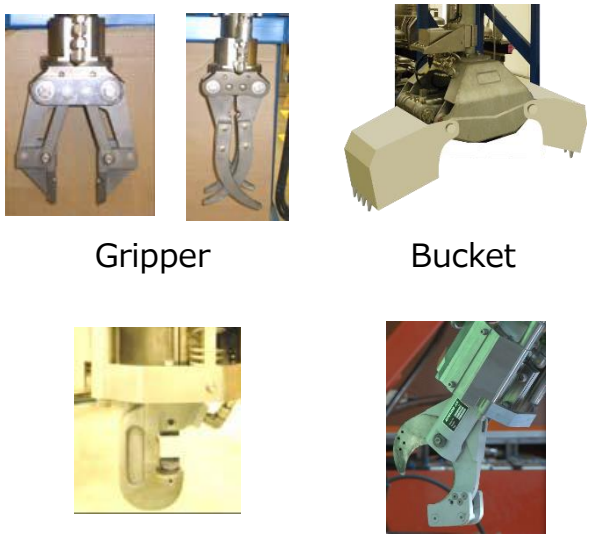
Image obtained during the investigation inside the pool in 2015

3-1. Rubble removal from the pool

- Small rubble covering the fuel will be removed using manipulators and different tools capable of vacuuming, gripping and cutting the fuel.
- If the dose level of the removed rubble is high it will be kept in the pool and relocated so it does not hinder fuel removal.
- After a test run of the fuel handling machine, small rubble above fuel handles will be removed first to gain experience. Small rubble around the fuel handle will then be removed after skill has been acquired.



Concept diagram of small rubble removal operation



Removal tool for small rubble

3-2. Fuel removal training with actual machine

- Training on the fuel handling machine and handling on-site transport containers will be implemented before the fuel removal.

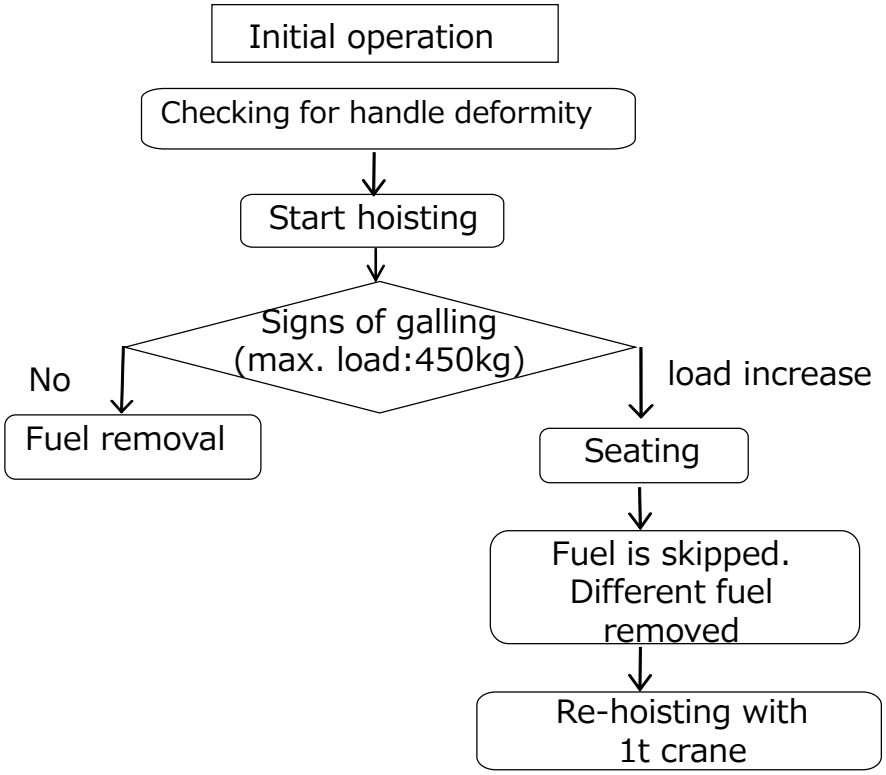
<Outline of training>

  - Training on remote operation of the fuel handling machine for removing fuel from the rack and putting it into on-site transport containers using simulated fuel
  - Training on remote operations including setting the on-site transport container in the spent fuel pool, screwing the lid on, checking the seal of the lid and hoisting the container
  - Training on the process of lowering the on-site transport container to the ground floor, attaching the secondary lid and loading the container on the vehicle

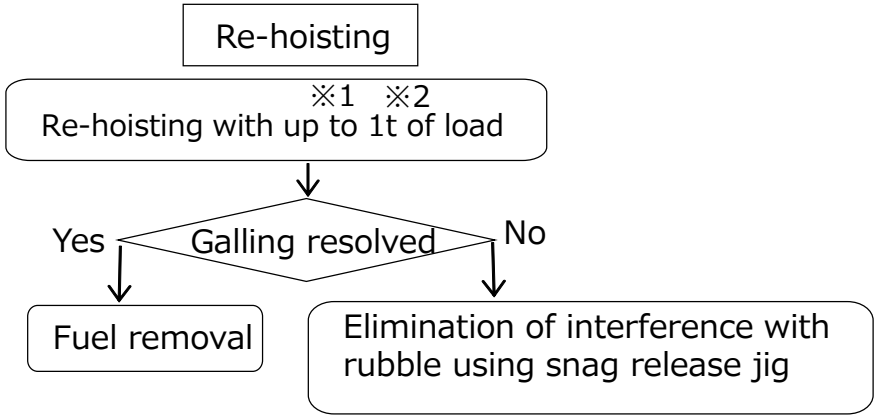
- Removal of the first on-site transfer container will begin after training on transporting a container has been completed. After transport of this first container is completed, the operation will be reviewed and procedures revised if necessary.

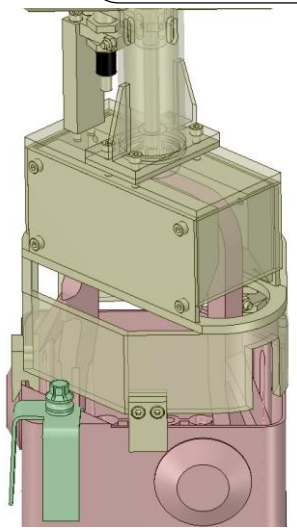
3-3. Fuel removal flow

- Underwater camera and jig used to check for handle deformities caused by rubble impact.
- If there is no deformity, hoisting starts.



(After removal of other fuel)





Jig to check fuel integrity

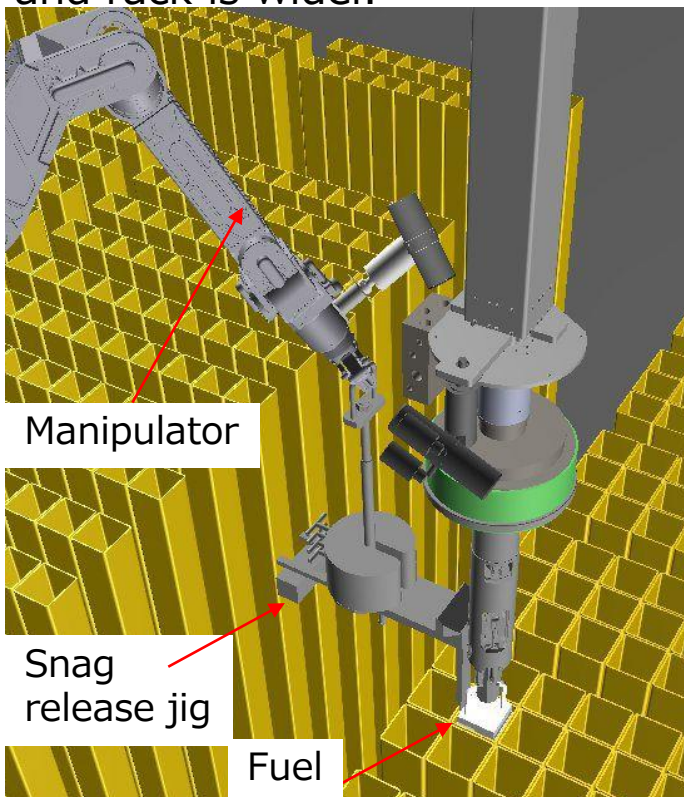
Check tilt and sinking of handle by covering fuel with jig

※1 Investigate cause of galling and use snag release jig if necessary

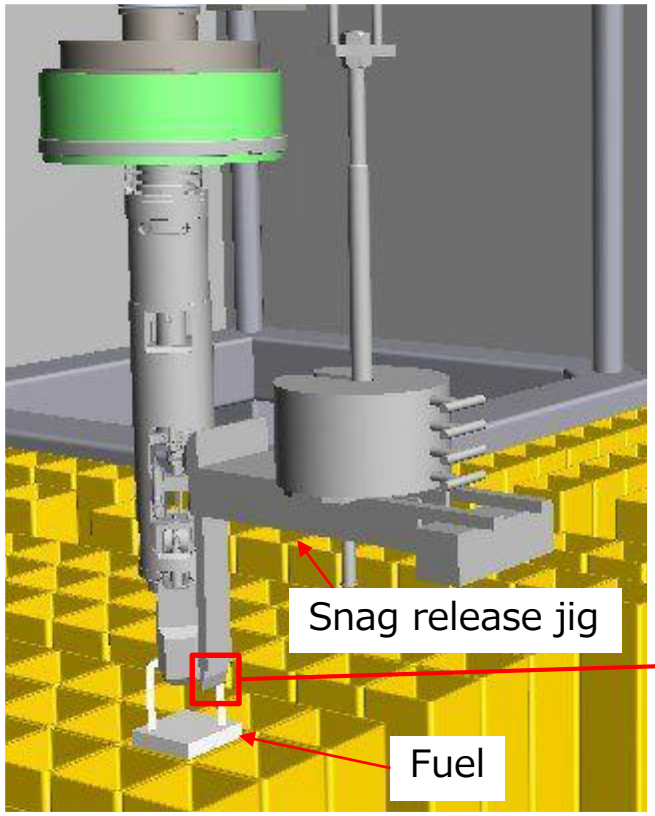
※2 To where the channel fastener exits the fuel rack

(Reference) Snag release jig

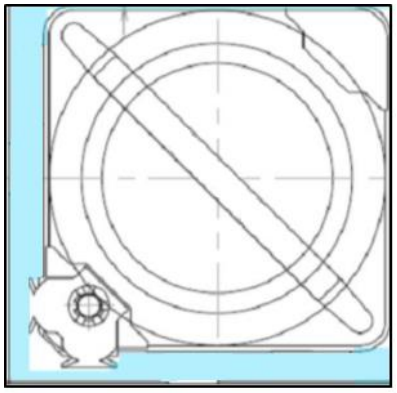
- Top area (entry) of the fuel rack is narrower than the inside dimension of the rack.
- Snag release jig is prepared for insertion into the gap between channel box (CB) and rack to drop rubble that might cause a snag at the top area of the rack which is narrower than the inside.
- The jig is inserted through the channel fastener side where the gap between the CB and rack is wider.



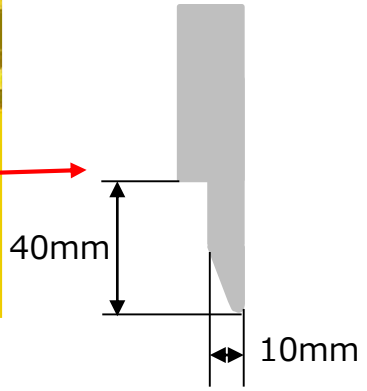
Concept diagram of snag release jig



From another angle

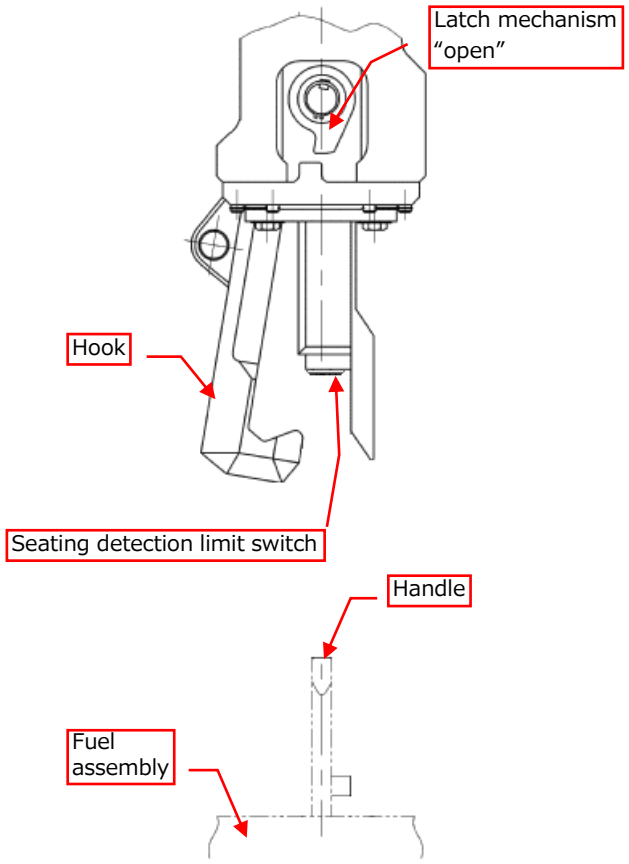


Jig insert range
(Blue area)



Shape of snag release jig top

3-4. Safety functions of the fuel gripper



Item	Measures
Checks during the fuel gripping process	Interlock to keep hook release position
	Detecting the seating of the mast by limit switch
	”Grip” detection limit switch
	Mechanical lock to keep hold at the hook gripping position
Fail-safe in case of power loss	Hook will not open if power is lost.
Mechanical interlock for hook	Mechanical lock prevents hook from opening when there is load on the hook.
Electrical interlock for hook	Electrical interlock prevents hook from opening when there is load on the hook.
Drop-prevention for fuel	Interlock preventing wire overload, multiple wires
Drop-prevention for fuel	Hoist motor has a negative load brake to prevent mast from dropping in the event of a power loss.
Soft interlock for hoisting and lowering	Movement stops if top of loaded hook is not pulled up to a certain height. Hoisting or lowering is stopped if excessive motion occurs during mast rotation
Interlock for movable range	Movable range is limited depending on hoist being used and object being hoisted.

3-5. Drop-prevention measures for the on-site transport container

TEPCO

- Redundancy and fail safe designs are the same as the existing fuel handling machine.
  - Redundancy of hoisting attachments and crane hoisting wires
  - Hook has a stopper mechanism.
  - Hoisting position is maintained by brake in case of a power loss.
- Seismic-resistance
  - A seismic response analysis was conducted for an earthquake during operation considering all load, including the hoisted object, and it was confirmed that the on-site transport container would not be dropped. The analysis used design basis earthquake ground motion Ss (600gal) for the fuel handling machine and elastic design ground motion Sd for the crane based on the Technical Code for Seismic Design of Nuclear Power Plants (JEAC4601-2008).
- Assessment of dose levels at site-border in the event that an on-site transport container is dropped
  - Simulated effective dose at site-borders in the event of a container drop would be sufficiently low at approx. 1.6×10^{-3} mSv.

4. Action for leaked fuel and fuel with handle deformity

- In Unit 3 there are fuel that leaked before the earthquake and also some that deformed as a result of the earthquake

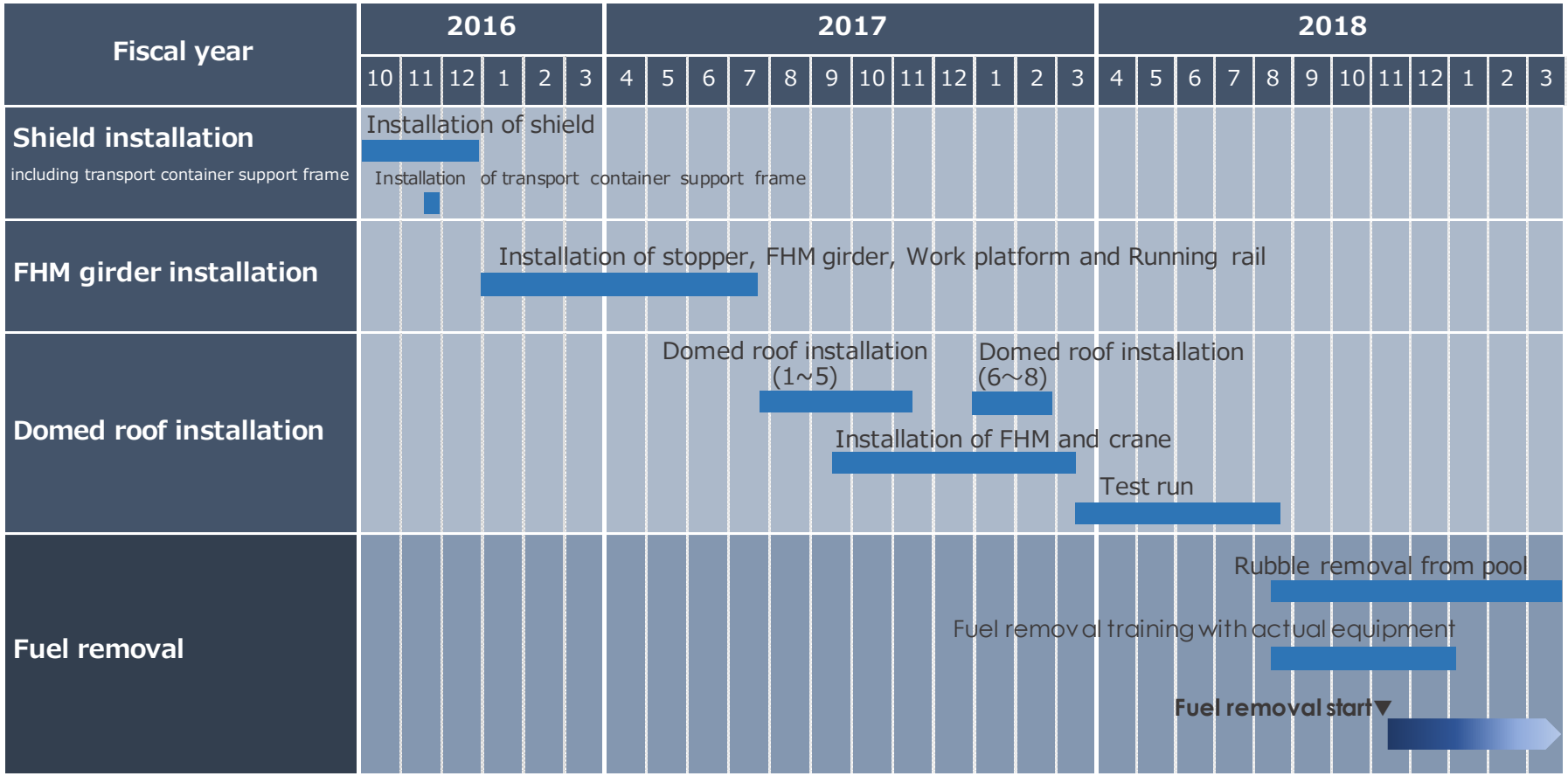
Time	Fuel status	Number of assemblies	Outline
Before the accident※	Offset spacer	1	Spacer was damaged due to nonconformity with rotating part of channel release when hoisting fuel after removing channel box for investigation.
	Partly damaged spacer	1	
	Partly damaged spacer (w/o CB)	1	
	Leaked fuel	1	Damaged during operation. Leak was detected during shipping test.
After the accident	Fuel with deformity of handle	6	Handle to grip fuel is damaged. Found during investigations inside the spent fuel pool and rubble removal (detected during investigations when deposits of rubble remained.).

- Fuel with offset spacers or partly damaged spacers will be handled in the same way as other fuel.
- Leaked fuel and fuel with partly damaged spacers (without CB) will be transported to the common pool after safety evaluation of the on-site transport container that considers damage to cladding tubes.
- Fuel with deformed handles will be transported to the common pool after the on-site transport container and the common pool rack have been renovated to accommodate the deformed handles.

※ Relevant fuel was mentioned in the modification permit application ”Fukushima Daiichi Nuclear Power Station, Implementation Plan of Specified Nuclear Facilities” on March 27, 2018 related to “Fuel removal from Unit 3 spent fuel pool, fuel handling and on-site transport container”.

5. Schedule for Unit 3 fuel removal

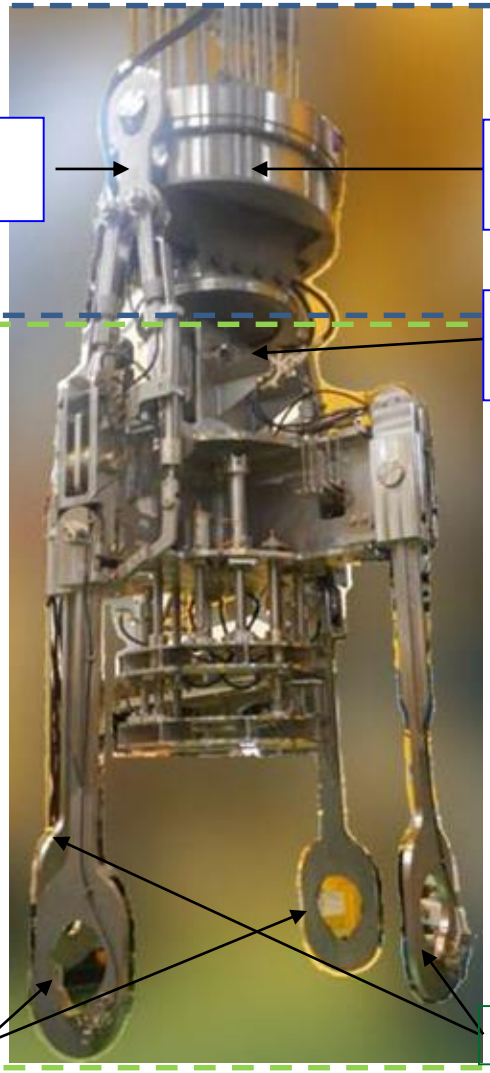
- Crane check restarted on July 14 after replacing parts in response to crane malfunctions, and normal operation has been confirmed. Test runs for FHM and crane are underway.
- Fuel removal is planned to start in November, 2018.
- We will continue to examine the schedule in further detail and move forward while making safety our top priority.



Reference

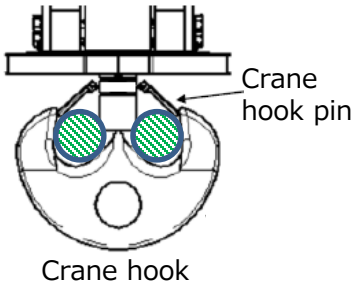
(Reference) Drop-prevention measures for on-site transport containers

Crane



Hoisting attachment

■ Redundancy of hoisting attachments



Connecting crane and hoisting attachment

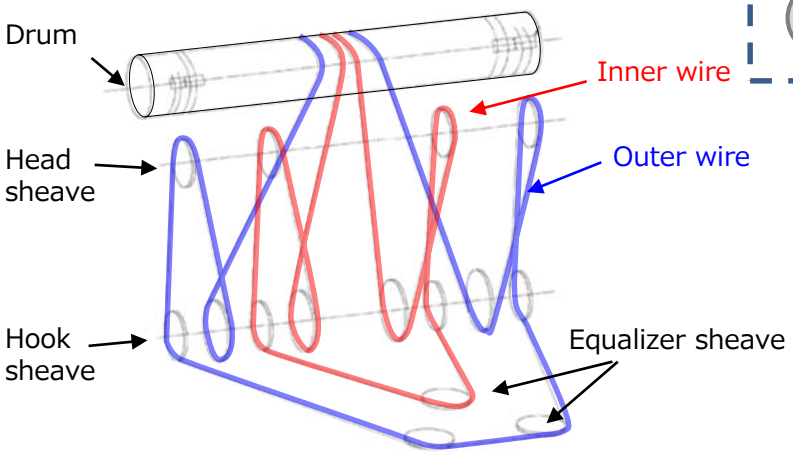
- 2 crane hook pins connect crane hook and hoisting attachment.
- Crane hook safety plate and bolt connect crane sheave and hoisting attachment.
- Crane hook is subjected to a load. If the crane hook is damaged, the crane sheave takes the load.

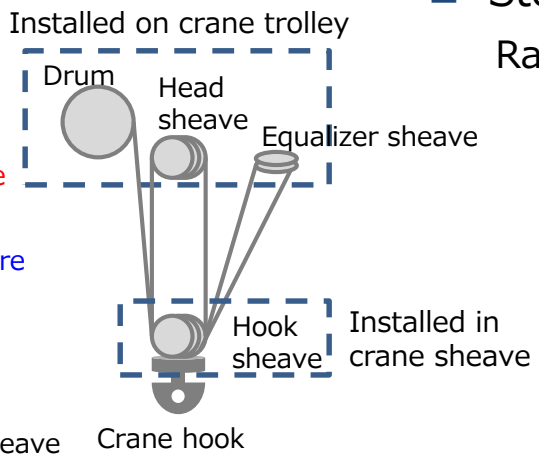
Connecting hoisting attachment and on-site transport container

- Main and auxiliary arms (one pair each) connect hoisting attachment and on-site transport container.
- Main arms are subjected to the load. If main arms are damaged, the auxiliary arms take the load.

(Reference) Anti-drop measures of the on-site transport container

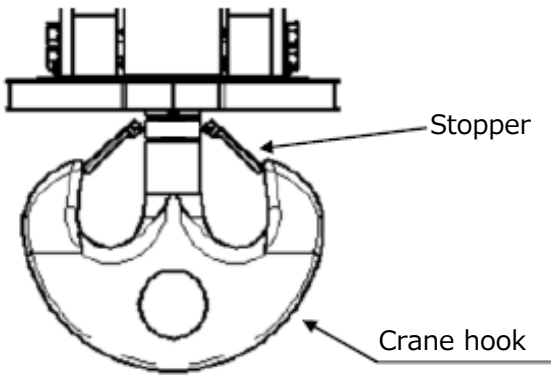
Duplicating hoisting wire of crane





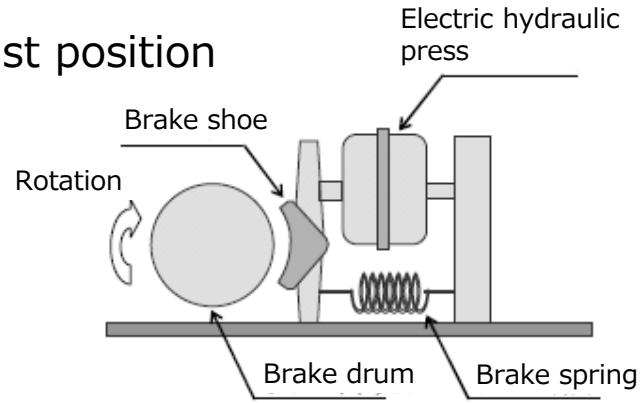
Stopper mechanism of hook

Ramshorn hook with stopper

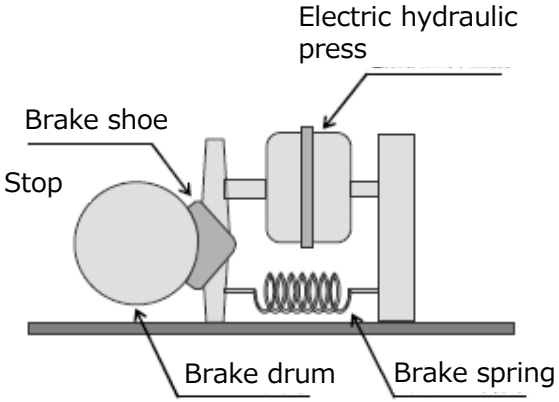


Crane brake maintains hoist position

If power is lost
and the electric hydraulic press stops, brake springs apply the brake to maintain the hoist position.



when applying current



when breaking

Fission product discharge volume

The amount of noble gas and iodine released into the atmosphere in the event of the drop of an on-site transport container and damage to all of seven fuel assemblies stored inside was assessed.

Fission product	Amount releases（Bq)
Noble gas	Approx. 1.3×10^{14}
Iodine	Approx. 6.6×10^{8}

Evaluation of effective dose equivalent

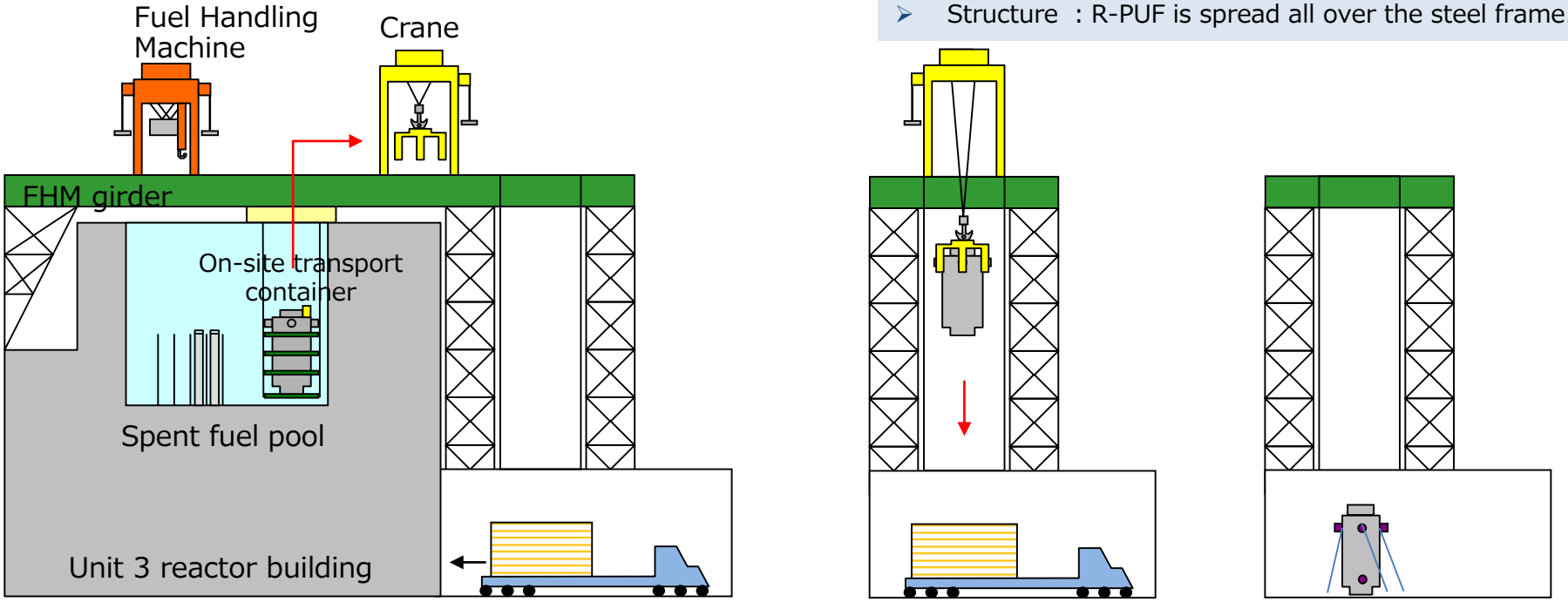
Effective dose equivalent was evaluated assuming that the fission products released into the air drop to the ground, and it was confirmed that the risk of radiation exposure to the general public in the vicinity would be low.

Fission product	Child (mSv)	Adult (mSv)
Noble gas	Approx. 8.6×10^{-4}	Approx. 8.6×10^{-4}
Iodine	Approx. 3.9×10^{-4}	Approx. 7.1×10^{-4}
Total	Approx. 1.3×10^{-3}	Approx. 1.6×10^{-3}

(Reference) Preparing for the drop of an on-site transport container

- Cushioning is prepared to absorb the impact in order to maintain the seal of the container if it is dropped.

Cushioning
- Dimension : Approx.3.4m × Approx.5.1m, Approx.5m in height (including vehicle)
- Material : Rigid polyurethane foam (R-PUF)
- Structure : R-PUF is spread all over the steel frame.



① Cushioning installed
② On-site transport container hoisted up

③ Container is lowered down to cushioning

④ Wires attached to prevent the container from toppling
⑤ Container loaded on vehicle after attaching the secondary lid

Concept diagram of lowering the on-site transport container to the ground