Fukushima Daiichi Nuclear Power Station

Fuel Removal from Reactor 4 Spent Fuel Pool

November 2013

Tokyo Electric Power Company, Inc.

TEPCO 東京電力

Is Reactor 4 Safe?

TEPCO is receiving many comments posing worries for the damage status concerning Reactor 4 when the great earthquake hit the area.
Many are worrying about the integrity of the building as well as the spent fuel pools, and about removing fuel from the pools.

As for removing fuel from the spent fuel pools of Reactor 4, we believe it is a great step forward toward stability and reactor decommissioning at Fukushima Daiichi Nuclear Power Station.

Removing fuel from a spent fuel pool is a normal operation that has been done at any nuclear power station, even before the great earthquake.

All the same, when the earthquake hit, a hydrogen explosion occurred at Reactor 4. In this sense, removing fuel entails a risk that is clearly different from normal operations, in terms of working environment.
We are determined to take assured actions against these risks, and if a problem is recognized during the process, we will confirm it carefully and will carry out operation under safety-first principles.

What is the status of Reactor 4 now?

When the accident occurred

- When the accident occurred, Reactor 4 was not in operation; **it was under regular inspection**. All fuel was removed from the reactor vessel and **stored in spent fuel pools.**
- All 1,500 fuel units **did not show fuel melting,** but a hydrogen explosion, possibly caused by hydrogen coming in from Reactor 3, occurred.

Current status of Reactor 4

- We are now preparing for removing fuel from the spent fuel pools. This is to be carried out by removing debris on top of the building and installing external walls around the building, and covering its ceiling. Actual works will start in November 2013.

Reactor 4 when the accident occurred

Reactor 4 with external walls and ceiling panels installed

Cover for taking fuel out

Why is it necessary to take fuel out of Reactor 4's spent fuel pools?

We believe it is safer to store all fuel in a common pool,

rather than store at each reactor's spent fuel.

- It is necessary to move fuel from each reactor building's spent fuel pools to a common pool, so as to store them in a more reliable condition.
- The common pool is planned to be used over a long period, supposedly for 10 to 20 years, and will be reinforced against possible future earthquakes and tsunamis.
- When preparation is completed, fuel from other reactors will be gradually transferred to the common pool.

東京電力

Can fuel be taken out in a safe manner?

Are there any problems with the building?

See P5 -8

✓Isn't the building tilted? Can it withstand another earthquake?
✓Is the building itself not damaged?
✓Can the fuel pool's bottom withstand the load of fuel?
✓Can the building withstand the weight of the fuel removal facility?

Scattering and diffusing of radioactive substances during the work

See P9,10

✓Aren't radioactive substances scattered out when fuel are transferred?
✓Is there any chance of nuclear reactions during the work?

How safe is the fuel taken out of spent fuel pools?

See P11-13

✓Is there any chance of damaging fuel hit with debris?
✓ What if an earthquake occurs while taking fuel out? Is there any chance of dropping them?
✓What will occur as a result if fuel drops?

Can the fuel taken out be managed appropriately? Can it be cooled in a safe manner?

See P14,15

✓Does the pool storing the taken out fuel have sufficient seismic resistance?
✓Is the cooling functionality sufficient? What if power to the pool were to be lost?

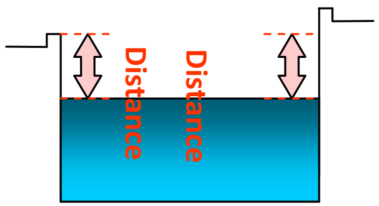
Isn't the building tilted? Can it withstand another earthquake?

Through regular inspections and computer analysis,
TEPCO has confirmed that the spent fuel pool and the buildings themselves are strong enough to withstand an earthquake with the strength equivalent to the 2011 earthquake off the Pacific coast of Tohoku (Seismic Level 6+).

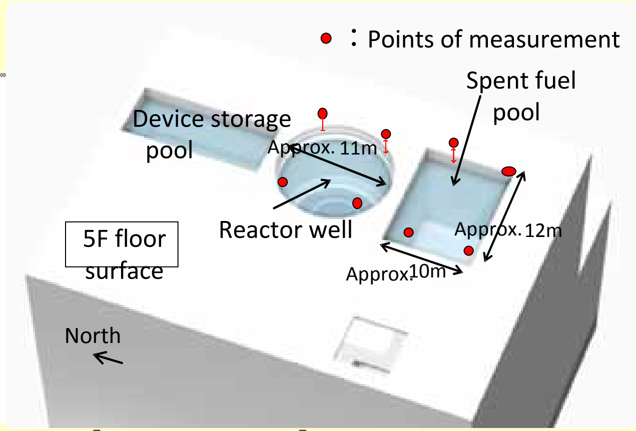
●Inspections confirmed that the building is not tilted.

・Using the fact that water surface is always horizontal, distances among the 5F floor surface, the reactor well, as well the water surface of the spent fuel pool were measured, and it was confirmed that the building is not tilted.

•The building isn't tilted.



The distances are almost same.



● Inspections confirmed that the building is free of any damage that may collapse the building.

・Checks have being made for cracks on the concrete bottom and wall.
・Non-destructive inspections confirmed the concrete strength and seismic safety.
・Checks and regular inspections are made, and necessary repairs are being carried out.

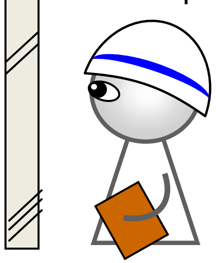
Measurement point		Concrete strength (Aug. 2013)	Design basis strength
Wall	1st floor	39.1	22.1
	2nd floor	34.0	
	3rd floor	39.8	
	4th floor	37.7	
Pool floor (base)		31.6	

Is the building itself not damaged?

●**Confirmation has been made on the integrity of the reactor building and spent fuel pool, by conducting approaches of building slanting measurement and regular inspection, including visual checks and concrete strength verifications.**

●Verification is made by visual checks to make sure there is no damage within the reactor building.

Visual inspection

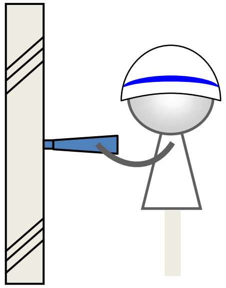


Wall supporting the spent fuel pool

- Periodic observations are being cautiously made by visual checks, such as verification of concrete floors and wall cracks.
- Appropriate maintenance is being conducted as needed.

●Periodic inspections are being conducted 4 times a year, and the integrity of the reactor building and spent fuel pool are verified.

*Non-destructive inspection (Schmidt hammer)



Concrete strength verification results

Measurement points		Concrete strength (Aug. 2013)	Guideline strength
Wall	1st floor	39.1	22.1
	2nd floor	34.0	
	3rd floor	39.8	
	4th floor	37.7	
Pool floor (base)		31.6	

- Non-destructive inspection is conducted, and concrete strength and seismic resistance safety verification is made.

東京電力

Can the fuel pool's bottom withstand the load of fuel?

Fuel pool walls and floors are constructed extremely thickly.
Above that, the entire pool is supported by an extremely thick seismic resistance wall.
Therefore, even should there be damage to the other outer walls and floor,
the same seismic resistance as before the earthquake is secured, and thus the floor will not fall out.

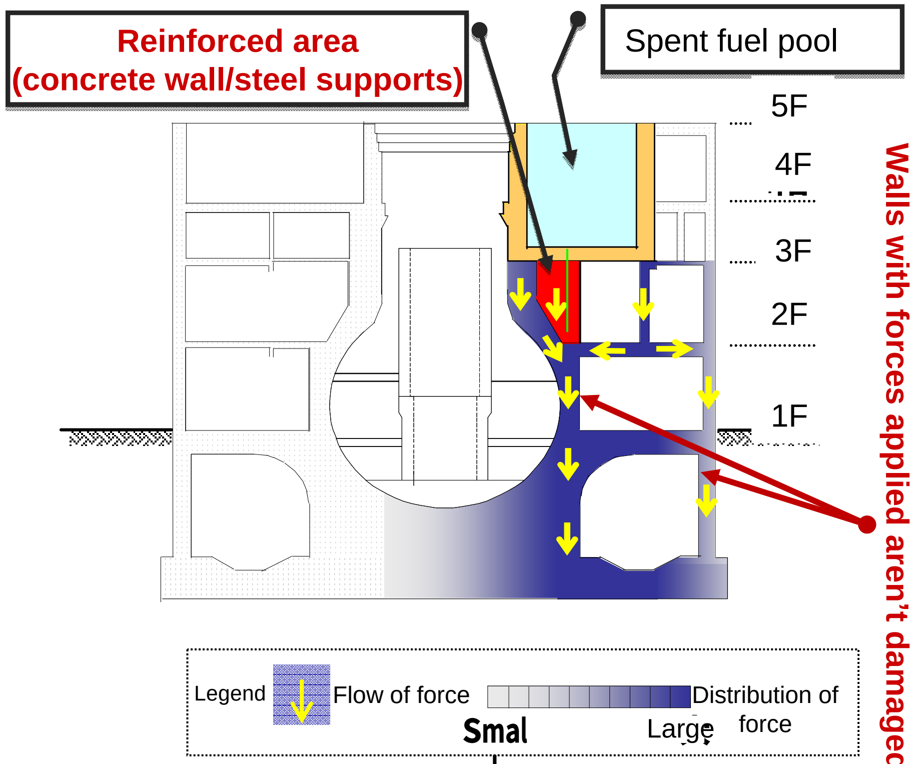
●Measures for enhancing water tightness have been carried out for the pool.

- The pool is made of iron-reinforced concrete, which is approx. 140 to 185 cm thick. It is also lined using stainless steel plate, which is approx. 6 mm thick.
- No pipes or drain holes penetrating through the pool's walls and bottom are installed.

●Seismic resistance has been further heightened.

- The bottom of the pool has been reinforced.
  Steel supports were installed at the bottom of the pool, and concrete was applied to make concrete walls.

*** The pool has a facility to replenish the water lost, should water leak out of the pool.**



Flow and distribution of forces applied to the spent fuel pool (image)
(Cross-sectional view of the reactor building)

Can the building withstand the weight of the fuel removal facility?

The facility is designed so as to avoid its weight being applied to the building to the extent possible.

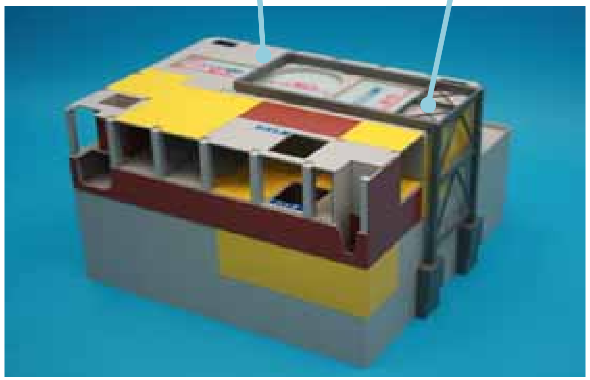
●A structure to support the fuel taking facility is installed so that works can be carried out without applying the weight of the facility onto the building.

Debris have been all removed from the top of the building (5F floor surface)

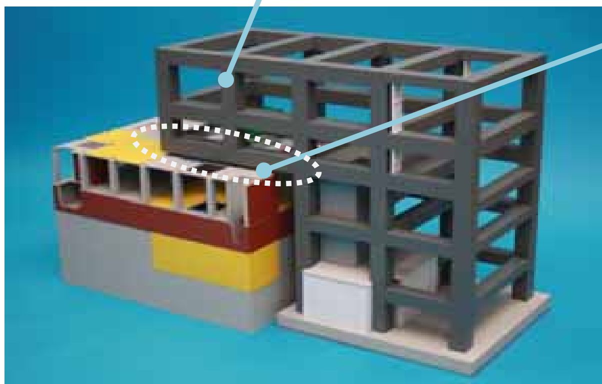
Bridge for supporting the fuel handling machine

Bridge for supporting the crane

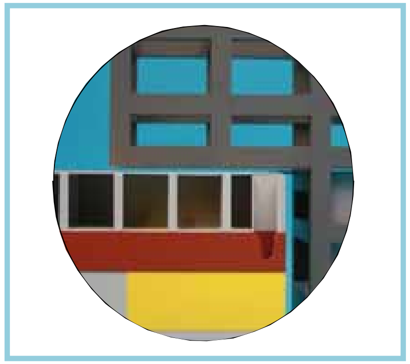
The crane supporting bridge is structured so that its weight is not applied onto the reactor building.



Bridge for supporting the fuel handling machine
(Southwest Side)



Bridge for supporting the crane
(Southwest Side)



【Legend and damage status】 ：Totally collapsed ：Partially collapsed ：No damages

Aren’t radioactive substances scattered out when fuel is transferred?

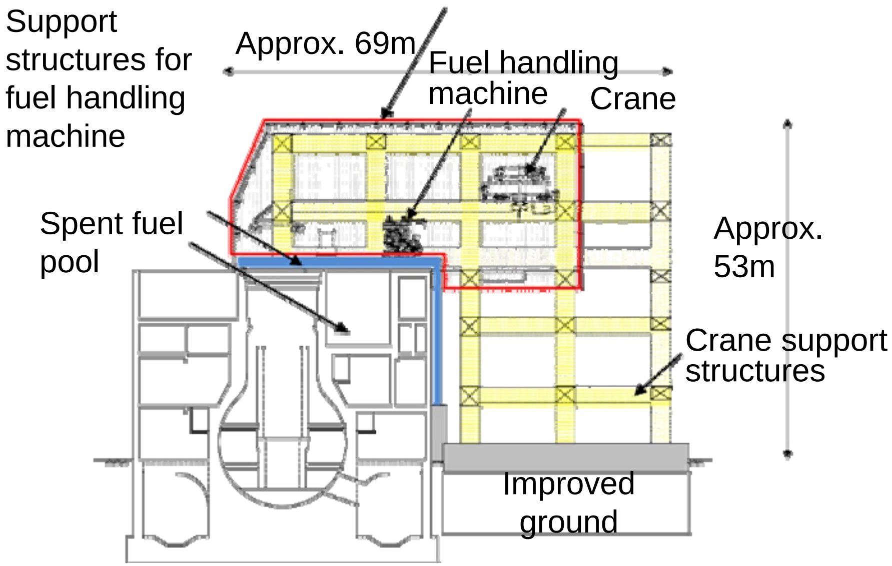
A ‘fuel cover’ will be installed to minimize scattering and diffusion of radioactive substances.

All fuel are taken out and transferred into transportation vessels under water in order to shield radiation.

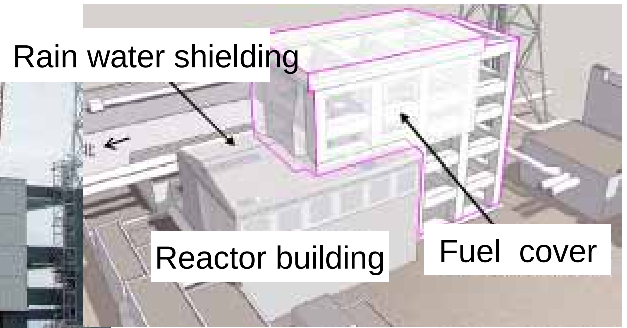
● Ventilation units will be installed inside the cover, which will discharge air to the outside of the cover through a filtering unit to minimize emission of radioactive substances out of the cover.

Outline of the fuel cover

Cover for fuel discharge (Within the red frame: Area where the working environment has been established)



Appearance and structure

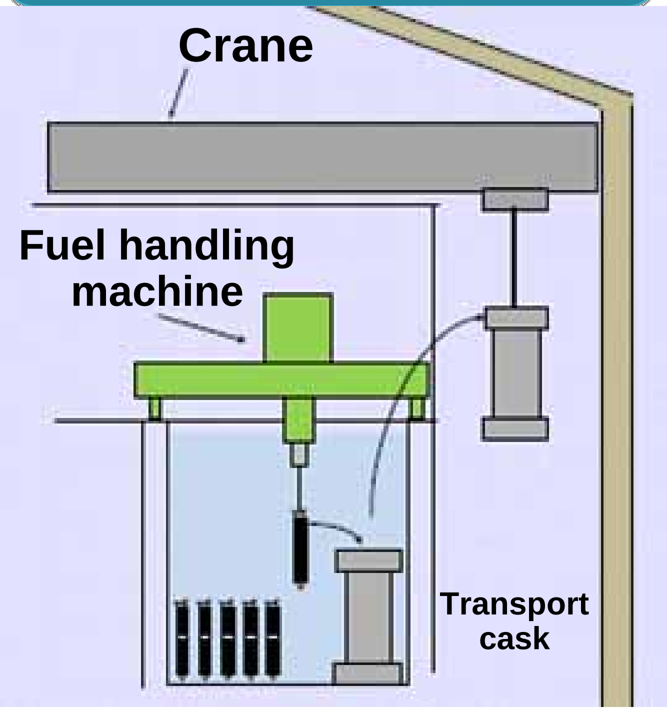


Installed on the floor and external walls (Southeast Side)

Is there any chance of nuclear reactions during the work?

Confirmation has been made that a single fuel cannot lead to a critical condition.
Work will be performed in a careful manner, one fuel at a time.

Underwater fuel removal
・Transfer methods to the transport cask etc.



- We believe falling of fuel is extremely unlikely to occur, since a system for detecting excess weight heavier than the fuel is used.
  - Whenever a fuel caught by debris is detected, hoisting is stopped to return the fuel back to its original position, or, the fuel is fixed.

- During the process, a check will be made one fuel assembly at a time for its intactness.

- Radiation exposure evaluation has confirmed that it does not exert serious risk to surroundings even if fuel should drop on other fuel.

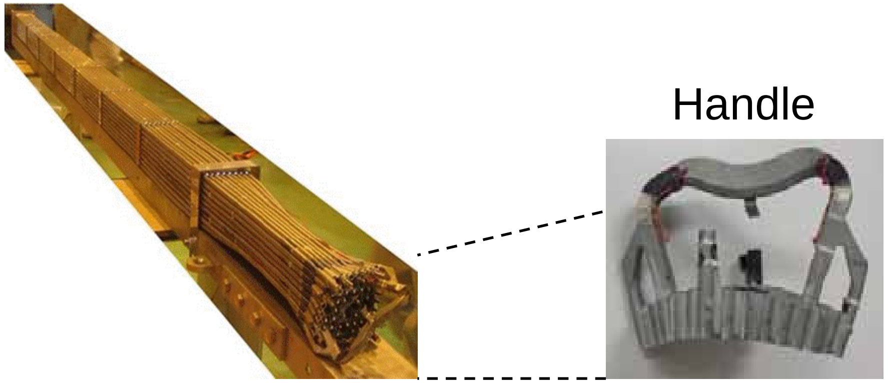
Is there any chance of damaging fuel hit by debris?

Debris in the pool will hinder the handling of fuel, and thus will be removed by special machines. Fuel pellets*1 are covered by fuel covering tubes*2 , as well as a channel box made of extremely strong zirconium alloy, separating the pellets and debris. Therefore the debris will not directly contact fuel pellets.

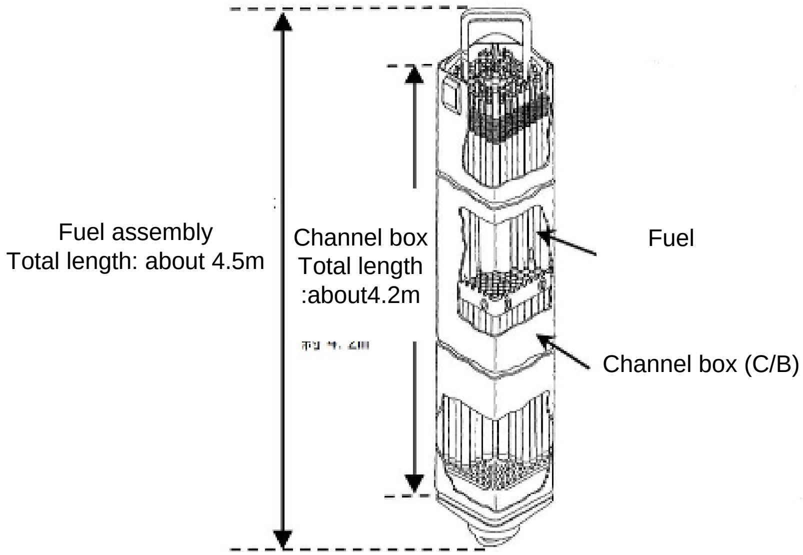
● A collision test has been conducted, simulating falls of debris onto fuel

●Falling of an 100 kg stone from the height of 5 m as an extreme case.

・The handle was significantly deformed and the fuel was bent. However, no hoisting performance and sealing tightness of fuel were sacrificed.



●Since fuel pellets(*1) are within the claddings and those are within channel box, they are protected from contact debris.



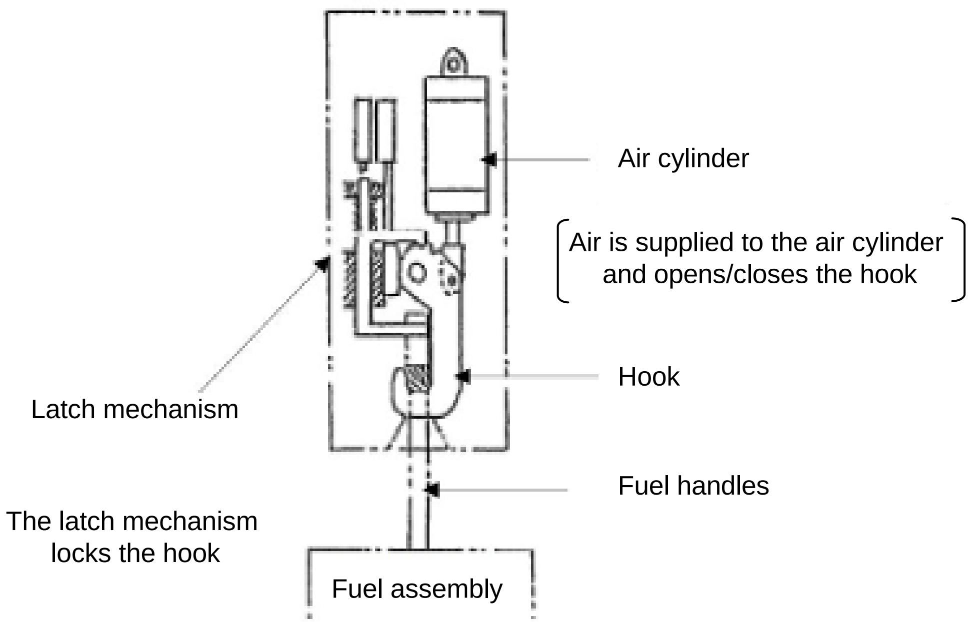
*1 Refers to fuel pellets, and creates fuel, which is one of the components of the reactor core. Its single size is about the tip of the pinky finger.
*2 Used for containment at the reactor so that radioactive materials released by nuclear fuel do not leak to the outside.

What if an earthquake hits while taking fuel out? Is there any chance of dropping them? What results will occur if fuel drops?

The fuel handling machine has multiple safety measures by doubling wires and brakes. Even if power is lost during the work, the hook would not open and would not drop fuel.
Confirmation has been made that a single fuel assembly cannot lead to a critical condition even if it is dropped.

● While hoisting fuel, the hook is locked and would not let go.

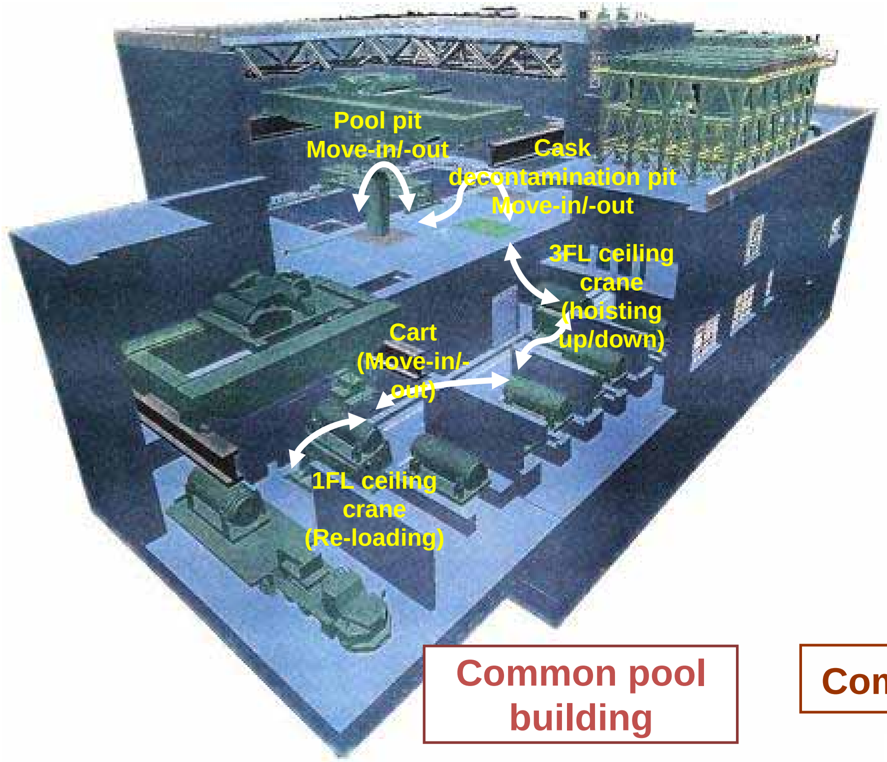
●The work of taking spent fuel has been done repeatedly at Fukushima Daiichi Nuclear.
Power Station and it is a proven work.
● Firmly based on the risks after the earthquake what situation is differ from the ordinary , the work will be done carefully and safely.

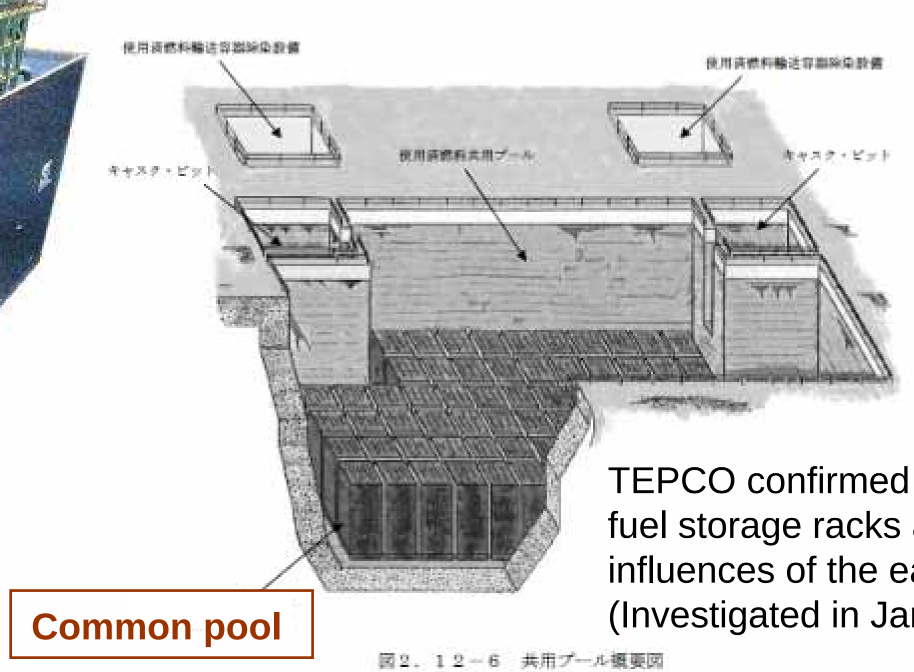


Does the pool storing taken out fuel have sufficient seismic resistance?

The common pool, though once its cooling function was lost temporarily due to the tsunami and the resulting power loss, provides stable cooling performance after early restoration of its major facilities. Since December 2012, it has been capable of handling fuel assemblies.

Common pool overview chart





TEPCO confirmed that the spent fuel storage racks are intact with influences of the earthquake (Investigated in January 2013)

Is the cooling functionality sufficient?
What would happen if power to the pool were to be lost?

In the event of a Tsunami, recover the cooling function promptly and return it to operation.
Ensure safety in the event of an emergency by diversifying the emergency power sources.

Perspective of Safety Measures

Diversification of “Cooling and Lockdown”

Secure cooling functions	Secure power sources	Measures against flooding
●Secure supply of water for the reactor and steam generator by deployment of fire pumps	●Secure power source for the central control room by deploying power source cars	●Waterproof measures implemented for power boards, batteries, pumps etc

Doors and holes are sealed

Source：FEPC

東京電力
TEPCO

Fukushima Daiichi Nuclear Power Station

Fuel Removal from Reactor 4 Spent Fuel Pool

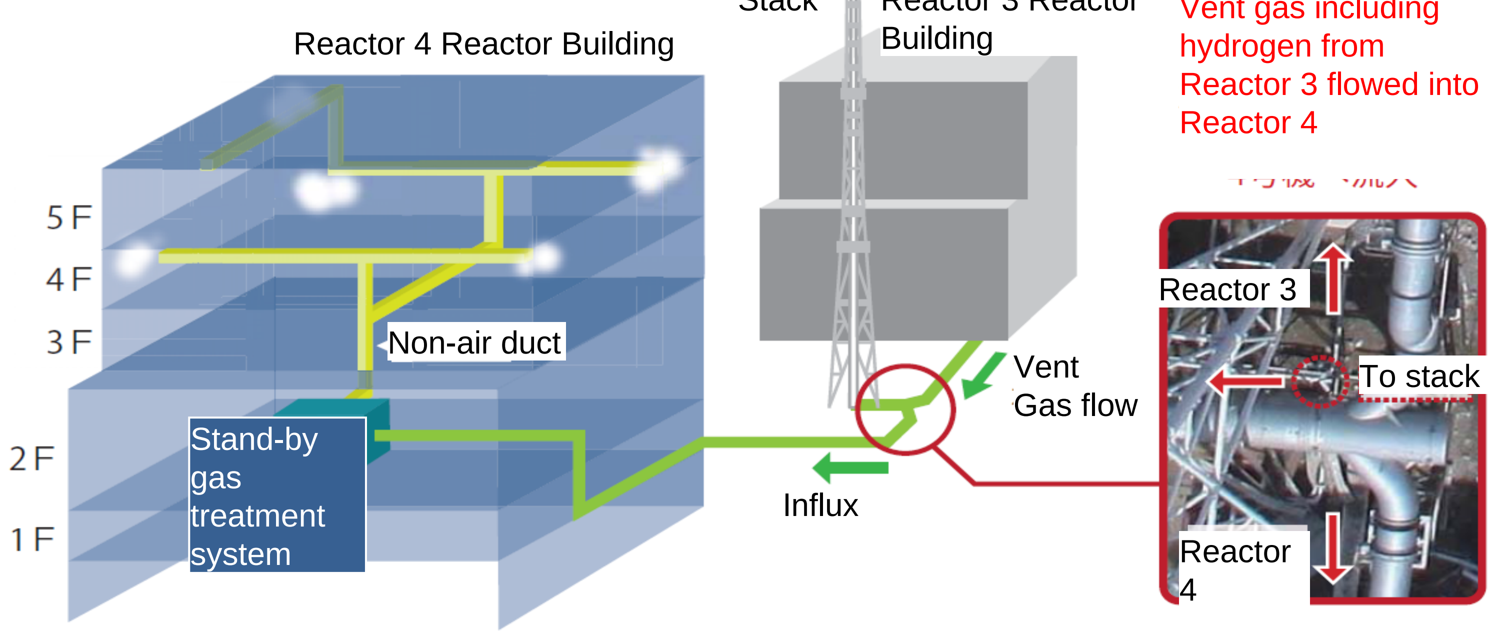
Q&A

Why did Reactor 4 explode?

It is thought that the hydrogen generated at Reactor 3 flowed into the Reactor 4 Stand-by gas treatment system / Building Ventilation System during venting(*1), which caused hydrogen explosion at Reactor 4.

● As for the main factor, regardless that Reactor 3 and Reactor 4 are have shared stacks, the Reactor 4 side Stand-by gas treatment system outlet valve was open during Reactor 3 vent operation.

***Hydrogen influx route to Reactor 4**



*1) "Vent" means the "action to release a part of the gas containing radioactive materials out of the PCV to the outside to reduce the increased pressure in the reactor.

Was the common Pool Damaged by Tsunami?

The Cooling function had been lost temporarily after the strike of Tsunami. However, prompt recovery of major facilities made the common pool be cooled in stable. The fuels in the pool started to be handled ordinarily on December 2012.

【Facilities that are considered as not affected by Tsunami】

Fuel Storage Facility	：Not Affected (External observation from operation floor, Sample checkup)
Spent Fuels	：Not Affected (Result of pool water analysis shows that most of the spent fuels are estimated to be sound from the)

【Facilities that are influenced and the action taken to be recovered】

Power Supply Facility	Cooling & Purifying Facility	Resupply Water System	Component Cooling System
Facility that supplies all the devices related to reactor	Facility that sustains the soundness of reactor by keeping reactor water to be high purity	Facility that provide condensate including radioactive materials	Facility that removes heat
Lost of power by flood	Stopped by Lost of Power	Stopped by Lost of Power	Stopped by Lost of Power
Installed temporary power supply facility in 11days after the earthquake	Recovered the cooling facility in 11days after the earthquake	Recovered one of the resupply water pump in 11days after the earthquake	Recovered the system in 11days after the earthquake

Are the "fuel" and "fuel pool" corroded due to seawater injection?

- Corrosion of the vessels and components was a concern because of seawater injection into the fuel pools. Therefore, we implement appearance checks for unused fuel removed from the Reactor 4 fuel pool, as well as inspection for corrosion of the fuel components.
- These inspection showed **that there were no corrosion which have effects on fuel integrity**.

Investigation of unused fuel in Reactor 4 fuel pool (Removed two assemblies of fuel in July, 2012)

- In July 2012, unused fuel were removed from the Reactor 4 fuel pool and were inspected.
- It was confirmed that there were no significant damages or corrosion on the surface of the removed fuel.
- Slight corrosion was detected on the part of lower tie plate, but it was not significant.

Inspection for corrosion of fuel components under the condition simulating the environment inside fuel pools (water quality, water temperature).

- Evaluation under the condition simulating the water environments in Reactor 4 where the largest volume of seawater was injected and in Reactor 3 where a mass of concrete was mixed.
- No significant corrosion was detected on the fuel.
- Although pitting corrosion can be found on stainless parts (upper/lower plate) on rare occasions, the occurrence rate is low. It was confirmed that there were no effects on fuel integrity.

Example of pitting corrosion on upper tie plate (90°C, Cl-density: 2500ppm, 2000hours, upper end plug is irradiated)

Are there any effects of dropped debris on the plastic deformation of fuel?

”Dropped Debris Collision Tests” were conducted regarding the concern of deformation of “fuel” in the situation in which debris fell from above during earthquakes. As a result, although there were handle deformations and bends in the fuel, elevation performance and safety of fuel sealing performance is ensured.

Evaluation of crushing impact on fuel based on the deformation level of the upper tie plate in the Reactor Building

◆ Flow of crushing impact caused by dropped debris in the spent fuel pools

Crushing on upper tie plate

↓

Crushing effect on expanded springs of fuel assemblies

↓

Impact to fuel claddings

↓

Crushing impact can be evaluated based on deformation level of the upper tie plate.

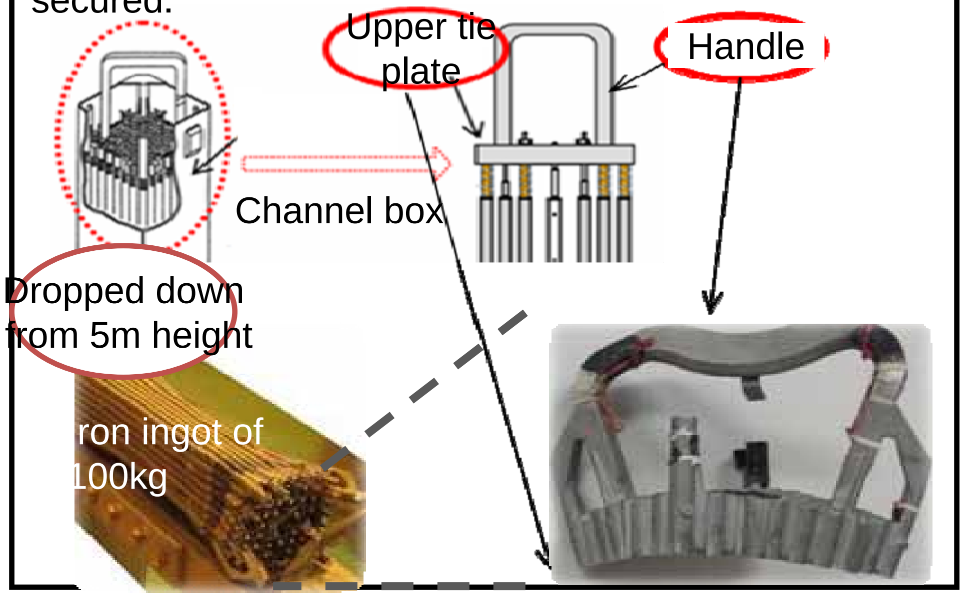
↓

Effects were confirmed through the Inspection of Impact Caused by Dropped Debris.

Results of Inspection of Impact Caused by Dropped Debris

*The handle was deformed significantly and the fuel were bended.

*The raising up function and fuel sealing function were secured.



Are there any effects from "bulky and small debris" on the removal operation?

The possibility that small debris that fell into cracks could become caught in channel box and fuel racks and cladding covering the fuel has been pointed out. Although TEPCO considers the possibility of debris becoming caught is quite low, operations are being conducted cautiously while monitoring loads. The fuel is within channel boxes, constructed of a strong alloy, so is protected from the dropping of debris and so on.

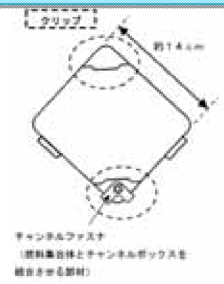
Preventing debris from becoming stuck and measures in response

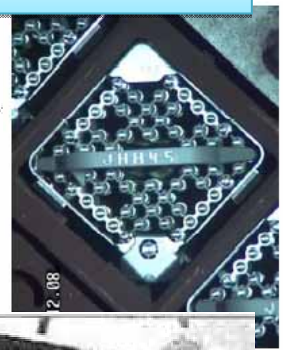
(1) Concerns about debris becoming stuck

Debris which has dropped into a 13mm-wide space and become stuck.

The occurrence rate can be estimated as low because the fuel assemblies and fuel racks are smooth.

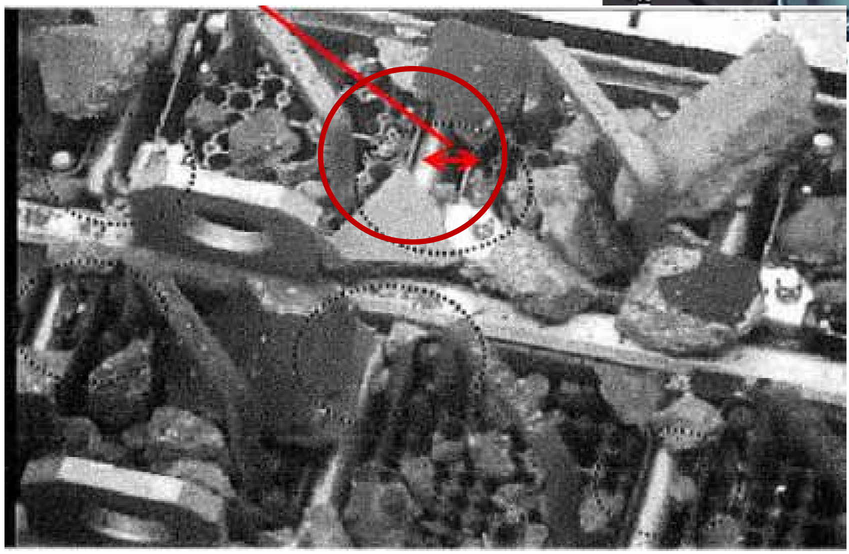
There is a 13mm space between boxes of fuel assemblies and fuel racks.





(2) Measures to prevent debris from becoming stuck

Remove as much debris as possible before the fuel removal operation.
Lifting speed: 1cm/sec (minimum speed.)
To avoid occurrence of trouble, TEPCO does not conduct operations on adjacent fuel assemblies simultaneously.



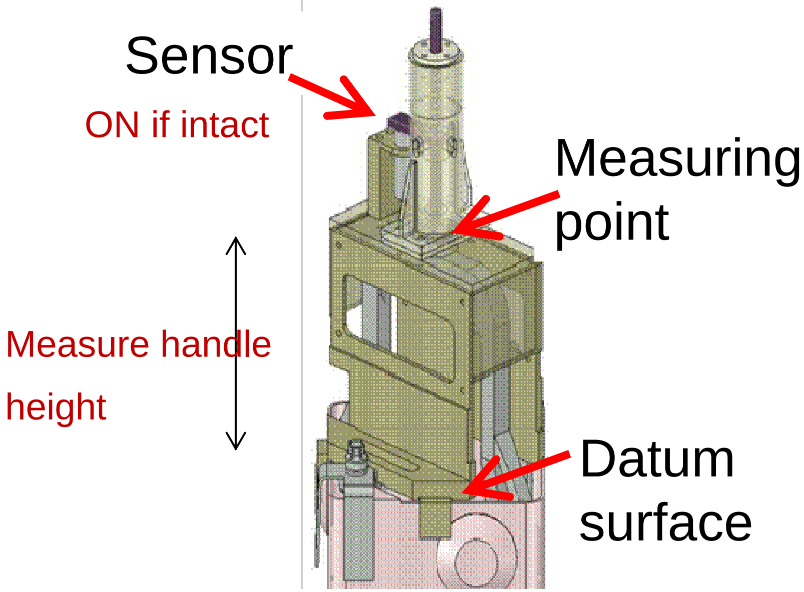
(3) Response measures if debris does become stuck

If a change of load is detected, the operation is stopped automatically.
If fuel assemblies become stuck with debris, change crane to prevent damage.
If fuel assemblies become stuck with debris, remove debris with specialized jig.

How do you measure the damage level of ‘fuel’?

“Fuel” damage is verified by the presence or absence of deformations on the “top tie plate.” The following specialized jig has been manufactured, and rods suspected of having been affected by debris are inspected for deformations before removal. The fuel is then carefully removed.

<Determining whether fuel is damaged or not>



Special device
(Integrity check jig)

● **Verify handle height**

Check whether the handle height is within guideline values or not.

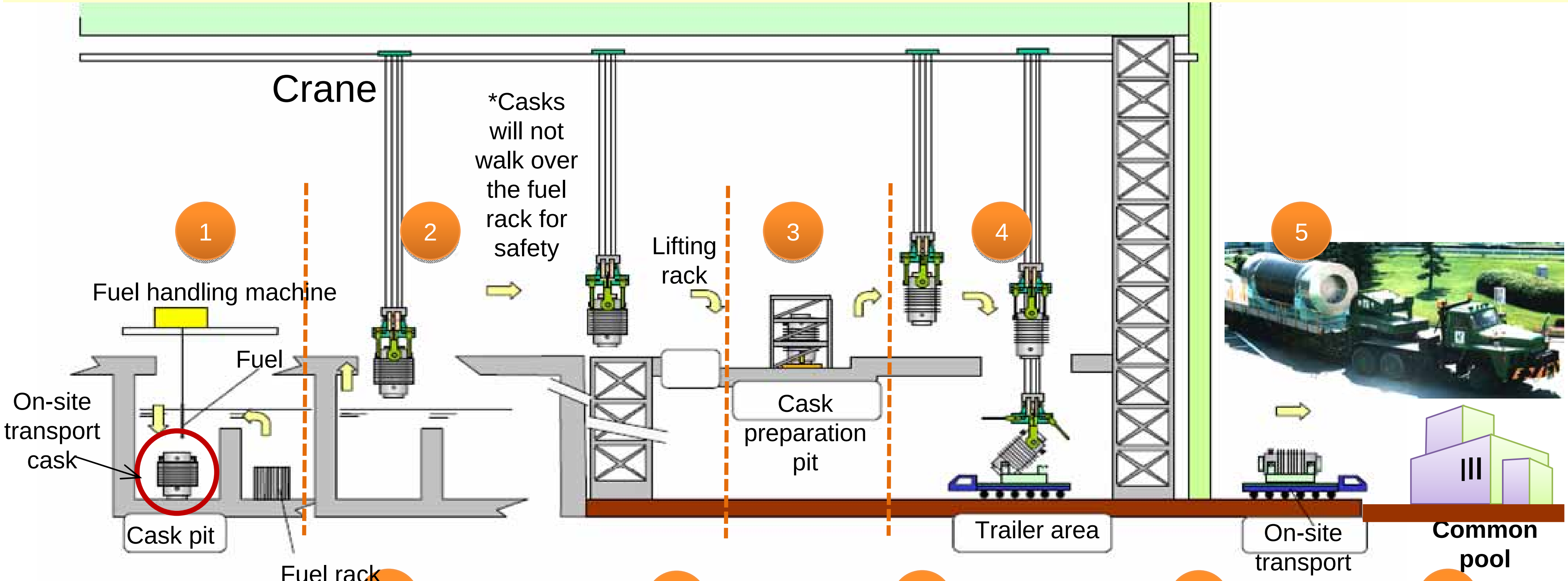
If handle is deformed, it is probable that fuel has been damaged.

● Verify whether the integrity checking jig (left illustration) fits or not

If the handle is bent by approx. 10 degrees, it will not fit. Thus, if it does not fit, this indicates deformation.

Transport process from cask pit

Perform on-site transport by using systems with same structures, design and safety as regular fuel handling. Cask pit transfer has a track record, being conducted more than 1200 times at TEPCO.



1 Grab fuel assemblies stored in the fuel rack and load them to the cask inside the cask pit (underwater)

2 Lift the cask from the cask pit and transport it to the cask preparation pit on the lifting rack inside the cover

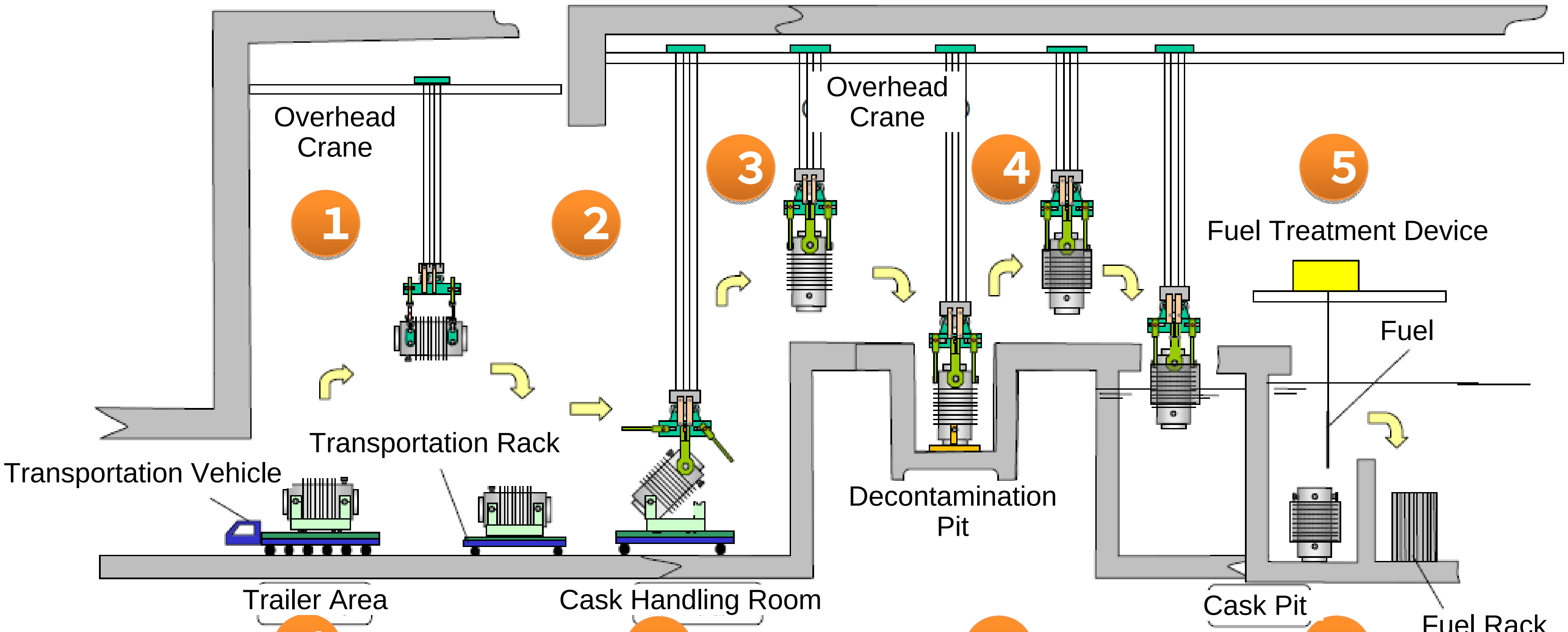
3 Seal the lid on the cask preparation pit and perform decontamination

4 Lift the cask by crane, put it down to the trailer area and load it to the transport vehicle

5 Transport the cask to the on-site common pool

Process of transferring spent fuel to the common pool after being boarded on a trailer

We will treat the spent fuel in the common pool in a safe manner, using facilities that have the same structure, design, and level of safety as our existing operation methods.



1. Board on transportation rack in the trailer area
2. Transport to cask handling room
3. Hoist the fuel in cask handling room and transport it to decontamination pit in the common pool area
4. Prepare for transportation in decontamination pit, and transport it to cask pit
5. Take the fuel from the (underwater) cask pit and place it on fuel rack

What should be done if the "fuel" removal with "fuel handling machine" is difficult?

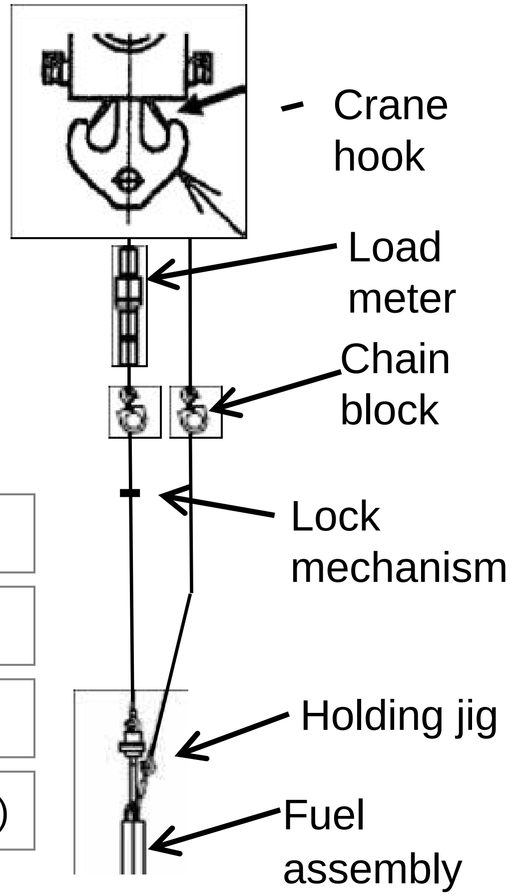
- If fuel removal with the fuel handling machine is difficult, such as in cases where a fuel gets stuck with debris, cranes shall be used to safely remove the fuel.

Fuel removal is conducted in safe by crane with a maximum withdrawal load of 1 ton as its safety load range.

- **The max load of the “fuel handling machine” is 450kg, and on the other hand the crane extraction load has the larger power to lift up to 1 ton. Even fuel stuck partially through can be safely removed.**

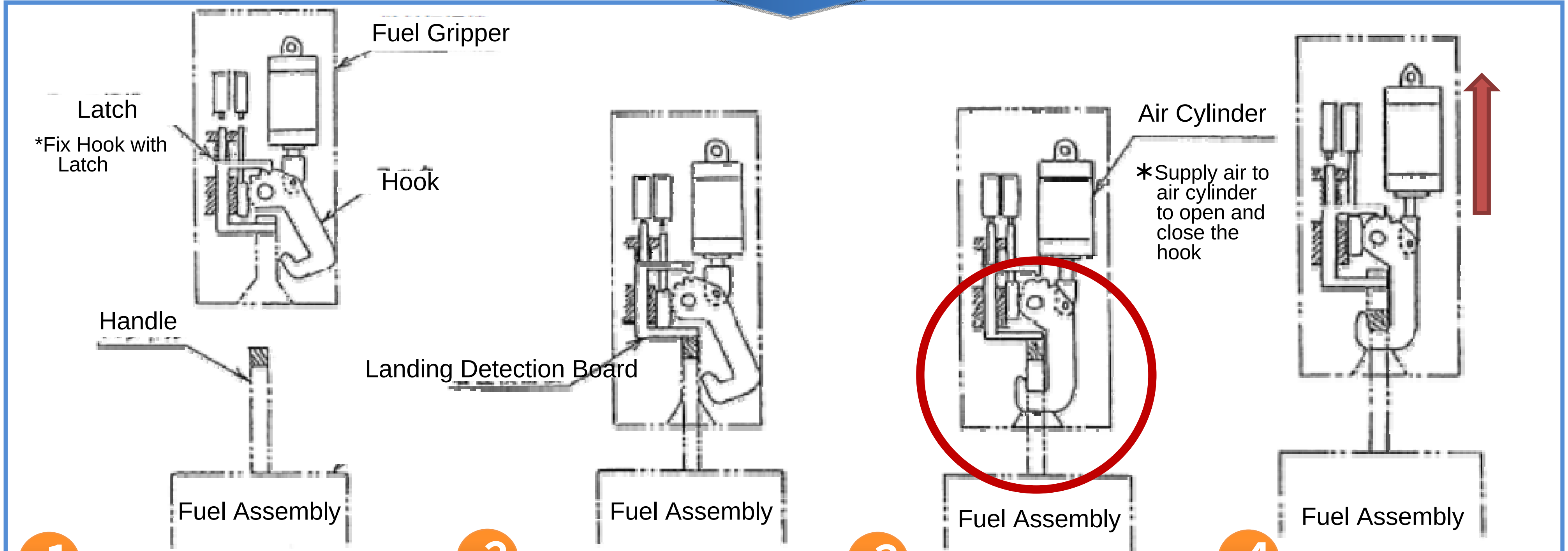
-Safety measures when using a crane-

Drop prevention (Double hanging)
Load monitoring
The load for fuel assemblies is limited up to 1t
Limit for lifting height (lock mechanism, prevention of extreme radiation exposure)



What is the mechanism to prevent the gripper losing contact with the fuel? (Interlock)

To prevent the fuel from falling, we will introduce following measures:
Interlock system: If the gripper is not holding the fuel handle correctly, the hoist operation will stop automatically.
Operator control panel: Operators can confirm each step, such as “Hoisting preparation complete” and “Hoisting complete” on the panel.



1 Hook: Open, Lower
- Fix the hook with the latch while open, then lower to the fuel assembly

2 Hook: Open, Landing
- Handle section of fuel assembly pushes up the landing detection board. Latch is unhinged

3 Hook: Close, Landing
- The hook is closed by driving air to it

4 Hook: Close, Raise
- Hoist the fuel assembly. The latch fixes the hook