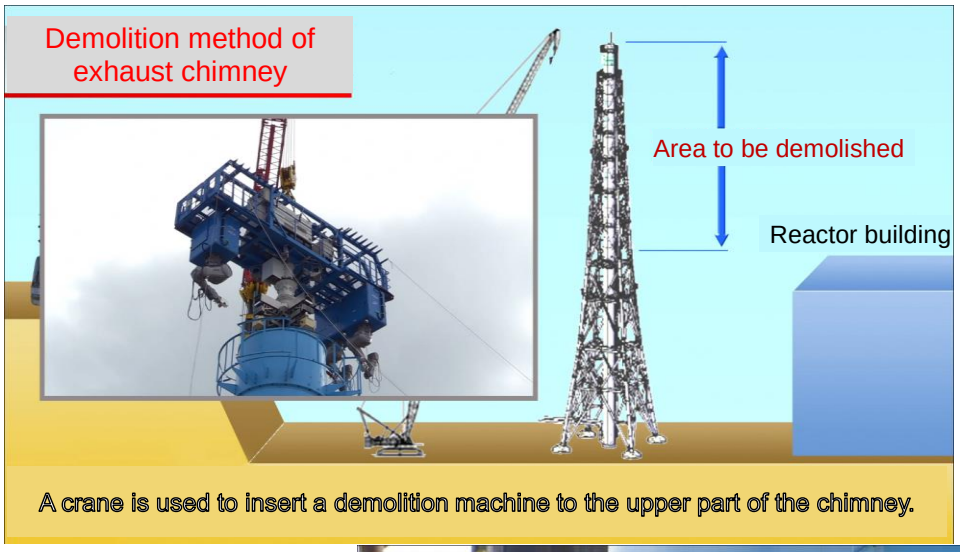
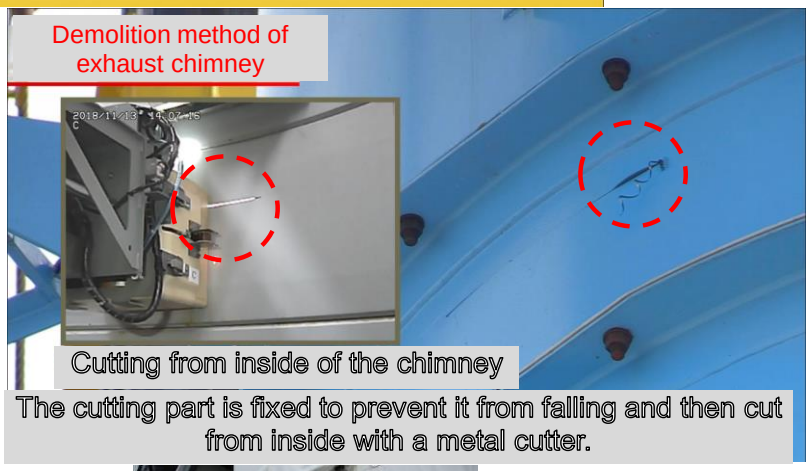
Commissioned by the Ministry of Health, Labour and Welfare
"FY2019 Project to Enhance the Radiation Exposure Dose Reduction Measures
for Works Relating to the Docommissioning of
TEPCO's Fukushima Daiichi Nuclear Power Plant"

Good Practices
in Radiation Exposure Dose Reduction Measures





Demolition of Unit 1/2 exhaust chimney by remotely-controlled robots
Source: ABLE

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Principles for Radiation Exposure Protection

(1) Reducing external exposure

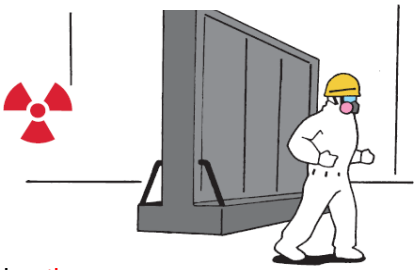
To reduce **external exposure,** it is important to understand the following four principles of radiation exposure protection.

Principle 1 Remove radioactive materials

Move radioavtive materials or wash out them from the inside of piping (flushing).

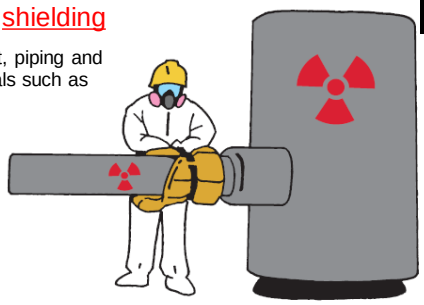
Principle 2 Maintain sufficient distance from radiation

If possible, move away from the radiation source and do not get any closer to it than required (also remember where the waiting areas are).



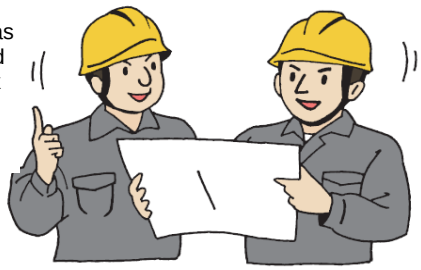
Principle 3 Install shielding

Cover radioactive equipment, piping and others with shielding materials such as leadwool or lead plates.



Principle 4 Reduce working time

Ensure sufficient preparation before conducting work, such as discussing procedures involved or inspecting tools so that work proceeds smoothly.



(2) Preventing internal exposure

To prevent internal exposure, it is important to wear the required personal protective equipment so that radioactive materials are not taken into the human body.

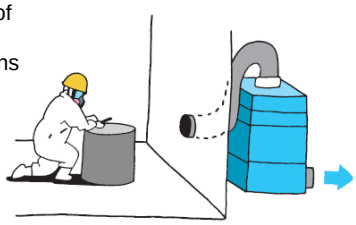
Measures also need to be put in place to prevent radioactive materials from being blown around in the air, as well as to contain (and limit) any contamination and stop it spreading (dispersing).

Principle 1 Wear protective equipment

Wear the required personal protective equipment and fit the respiratory protective equipment properly so that there are no leaks in.

Principle 2 Utilize equipment and materials

For work where there is the risk of dust being blown around, utilize temporary shelters or exhaust fans with filters.

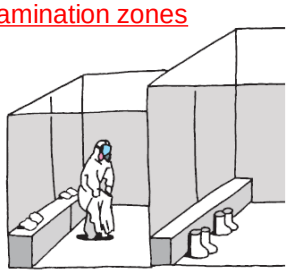


Principle 3 Move to safety

Move to a non-contaminated area immediately in the case of injury.

Principle 4 Clearly outline contamination zones

Clearly outline contamination zones and ensure full control and management of access to the zone. Cover any objects being taken out of the contamination zone with a sheet or similar material to prevent spreading (dispersing) contamination.



1F Site Operation Zone Control

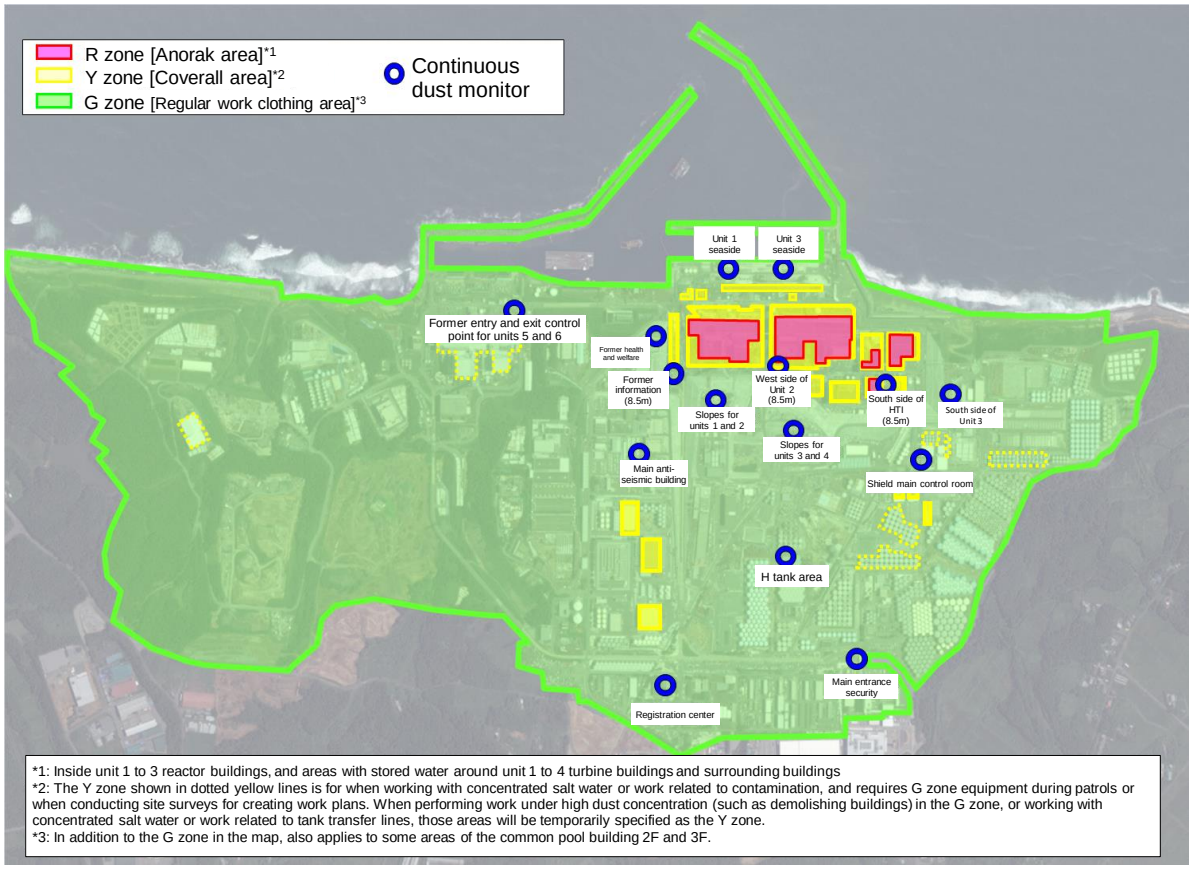
(1) 1F site operation zone status

Zone		Protective Equipment
Red zone (Anorak areas) - Inside unit 1 to 3 reactor buildings - Area with stagnant water around unit 1 to 4 buildings		- Full-face mask - 2 layer coverall or anorak - Work boots (for R zone) - Helmet (for R zone) - Cotton gloves + rubber gloves
Yellow zone (Coverall areas)	- Inside buildings that include water treatment facilities (such as desalinization units, multi-nuclide removal facilities) - Work in areas around tanks that contain concentrated salt water, strontium-treated water*1, and work that involves the handling of transport lines to tanks	- Full-face mask - Coverall - Work boots (for Y zone) - Helmet (for Y zone) - Cotton gloves + rubber gloves
	- Around unit 1 to 4 buildings - Specified as required to suit work environment (such as inside unit 5 and 6 buildings, parts of storage areas for high-radiation exposure dose rubble)	- Half-face mask - Coverall - Work boots (for Y zone) - Helmet (for Y zone) - Cotton gloves + rubber gloves
Green zone (Regular uniform areas) Areas except the above: Changed from Y to G on and after March 30, 2017. Part of peripheral area of Unit 1 to 4 buildings and slope faces of Units 1 to 4		- DS2 mask - Site clothing, regular work clothing*2 - Work boots (for G zone) - Helmet (for G zone) - Cotton gloves + rubber gloves or work gloves
- Inside important anti-seismic buildings and inside rest areas		

*1: Excluding work that does not involve the handling of concentrated salt water, tank patrolling, field surveys in the work planning phase, observation visits, etc.
*2: Certain light work (such as patrolling, monitoring and transportation of items brought in from outside the premises).

(Material provided by Tokyo Electric Power Company Holdings, Incorporated.)

(2) 1F site area map



Contents List of Good Practices in Radiation Exposure Dose Reduction Measures

No.	Location	Category	Title	Radiation exposure dose equivalent (mSv)			Notes
				Before Implementation	After Implementation	Reduction amount	
01-01	RB	3	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6	2,544	899	1,645	
01-02	RB	5	Remote operation of heavy machines and robots	3,907	2,189	1,718	
01-03	RB	5	Heavy machine operation by robot	3,907	2,189	1,718	
01-04	RB	5	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6	626	63	563	
01-05	RB	5	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6	450	28	422	
01-06	RB	7	Gantry steel frame assembling with prefabricated construction method	3,907	2,189	1,718	
01-07	RB	7	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6	--	--	--	
01-08	RB/TB	3	Tentative shielding before installation of retained-water discharging equipment	--	--	--	2.0 to 0.45 mSv/h, etc.
01-09	RB/TB	7	Tentative shielding before installation of retained-water discharging equipment	--	--	--	
01-10	RB/TB	7	Tentative shielding before installation of retained-water discharging equipment	--	--	--	
01-11	R	4	Decontamination of the entire building areas to reduce the dose rate	--	--	--	
01-12	R	4	Decontamination of the entire building areas to reduce the dose rate	--	--	--	
01-13	Y	3	Unit 1/2 stack disassembly using robots	--	--	--	0.7 to 0.01 mSv/h
01-14	Y	3	β ray shielding at the bottom of the tank due to disassembly of flange-tank	--	--	--	5.71 to 0.90 mSv/h (βγ ray)
01-15-1	Y	4	Utilization of laser decontamination when disassembling flange-type tanks	179.7	127.0	52.7	Exposure of eye lens/skin from β rays
01-15-2	Y	4	Utilization of laser decontamination when disassembling flange-type tanks	179.7	127.0	52.7	Exposure of eye lens/skin from β rays
01-16	Y	6	Remote-controlled contamination containment in disassembly of flange-tanks	24.89/tank	0.00/tank	24.89/tank	Exposure of eye lens/skin from β rays
01-17	Y	6	Unit 1/2 stack disassembly using robots	--	--	--	
01-18	Y	6	Unit 1/2 stack disassembly using robots	--	--	--	
01-19	Z	7	Visualization of exposure / Visualization of contamination	--	--	--	
01-20	Z	7	Exposure simulation	--	--	--	
01-21	Z	7	Remote monitoring system (RMS) utilization (1)	--	--	--	
01-22	Z	7	Remote monitoring system (RMS) utilization (2)	--	--	--	

Good Practices in Radiation Exposure Dose Reduction Measures

Location		Category	
Inside reactor building	RB	1	Time
Inside turbine building	TB	2	Distance
R ZONE	R	3	Shielding
Y ZONE	Y	4	Removing radiation source
G ZONE	G	5	Remote-control, robot operation
Other ( )	Z	6	Preventing spread of contamination
RB		7	Other

No.	01-01

Title	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6
Work location	Unit 2 reactor building 1FL
Overview	Obstacles are removed to carry in machines in X-6 on Unit 2 reactor building 1FL.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	2,544	899
	Person time (person-days)	--	--

Good Practice Description

Before Implementation

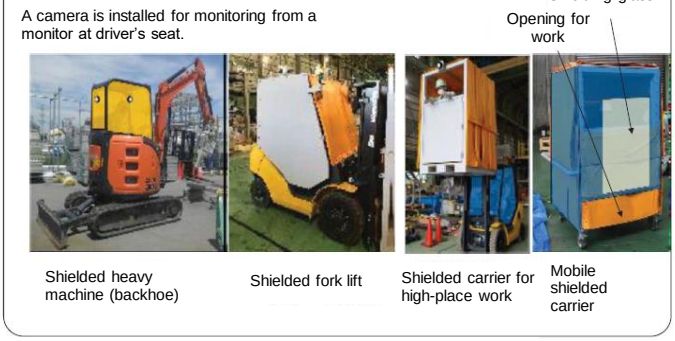
Unit 2 reactor building 1FL, the main working area, had a high dose rate and there was a concern that people could be severely exposed to radiation if machines were moved manually.

Implementation Details

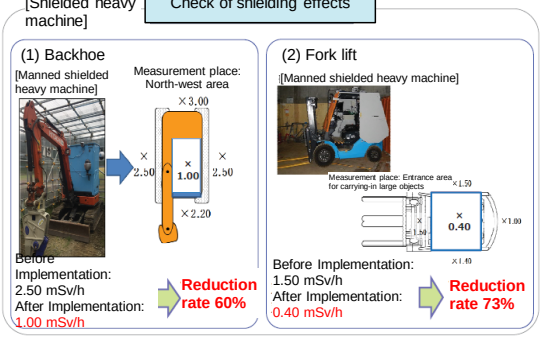
Various shielding measures were taken as shown below to minimize the exposure of workers.

<Engineering-type exposure dose reduction measures>

Heavy machine shielding, shielded carrier

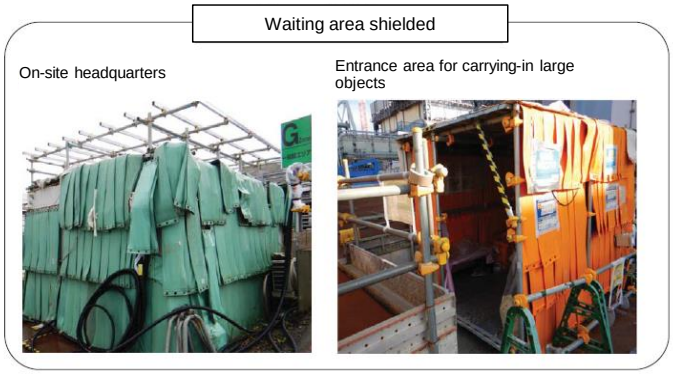


[Shielded heavy machine] Check of shielding effects

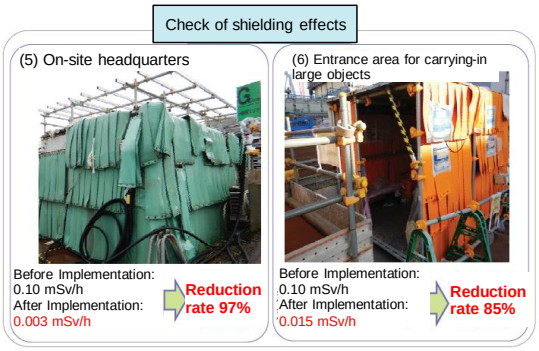


<Engineering-type exposure dose reduction measures>

Waiting area shielded



Check of shielding effects



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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	(RB)	RB	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y		4	Removing radiation source
G ZONE	G		(5)	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

5

No.	01-02

Title	Remote operation of heavy machines and robots
Work location	On roof of and around reactor buildings of Units 1 and 2
Overview	Heavy machines and robots were remotely operated to reduce human-power work.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	3,907	2,189
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

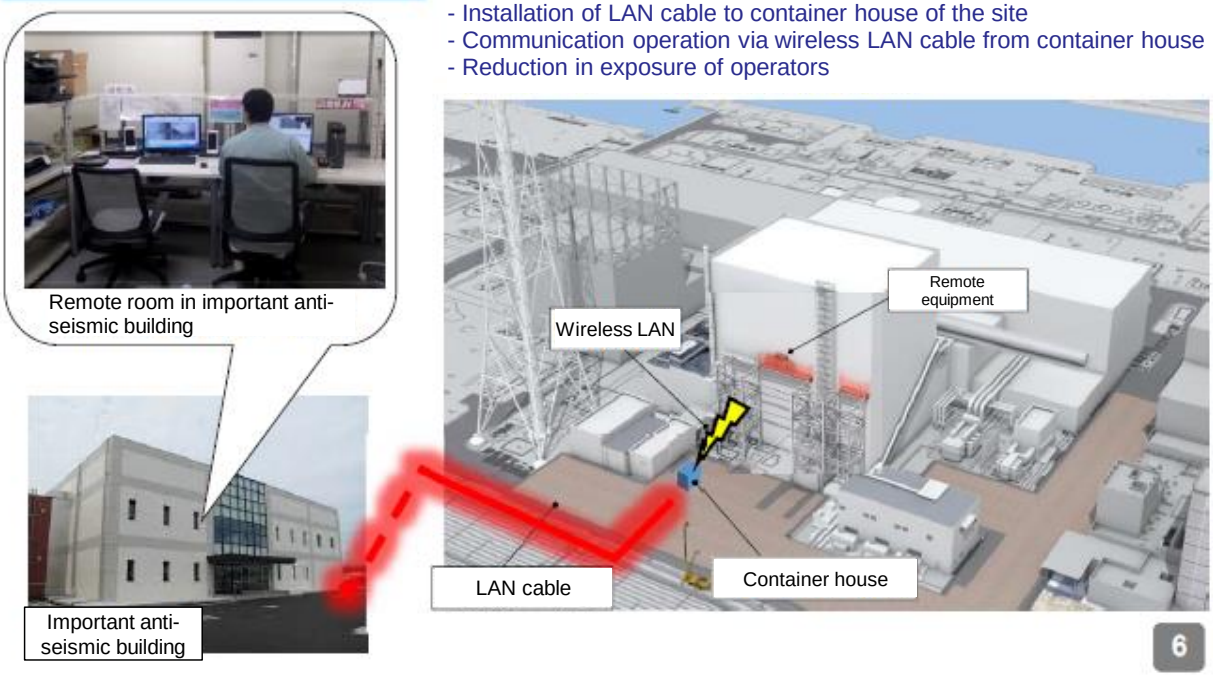
The areas on the roof of the reactor buildings and around the buildings had a high dose rate and there was a concern about people's severe exposure to radiation.

Implementation Details

Heavy machines and robots were remotely operated if possible to minimize human-power work.

Overview of remote operation system

- Remote operation from a remote room in the important anti-seismic building
- Installation of LAN cable to container house of the site
- Communication operation via wireless LAN cable from container house
- Reduction in exposure of operators



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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	(RB)	RB	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y		4	Removing radiation source
G ZONE	G		(5)	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

No.	01-03

Title	Heavy machine operation by robot
Work location	Outside Unit 1 and 2 reactor buildings
Overview	Heavy machines are operated by using robots around Unit 2 reactor building.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	3,907	2,189
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

The areas on the roof of the reactor buildings and around the buildings had a high dose rate and there was a concern about people's severe exposure to radiation.

Implementation Details

Heavy machines and robots were remotely operated if possible to minimize human-power work.

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Location			Category		
Inside reactor building	(RB)	RB	5	1	Time
Inside turbine building	TB			2	Distance
R ZONE	R			3	Shielding
Y ZONE	Y			4	Removing radiation source
G ZONE	G			(5)	Remote-control, robot operation
Other ( )	Z			6	Preventing spread of contamination
				7	Other

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-04

Title	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6
Work location	Unit 2 reactor building 1FL
Overview	Obstacles are removed to carry in machines in X-6 on Unit 2 reactor building 1FL.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	626	63
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

Unit 2 reactor building 1FL, the main working area, had a high dose rate and there was a concern that people could be severely exposed to radiation if machines were moved manually.

Implementation Details

Machines shown below that can be operated with a robot or remotely were used to minimize human-power work.

<Engineering-type exposure dose reduction measures>

Making a heavy machine unmanned and its remote operation

Remotely operated heavy machine

Husqvarna

Remote transportation carrier

Remote monitoring robot

Cobra

Packpod

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	RB	5	1	Time
Inside turbine building	TB			2	Distance
R ZONE	R			3	Shielding
Y ZONE	Y			4	Removing radiation source
G ZONE	G			(5)	Remote-control, robot operation
Other ( )	Z			6	Preventing spread of contamination
				7	Other

No.	01-05

Title	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6
Work location	Unit 2 reactor building 1FL
Overview	Obstacles are removed to carry in machines in X-6 on Unit 2 reactor building 1FL.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	450	28
		Person time (person-days)	--	--

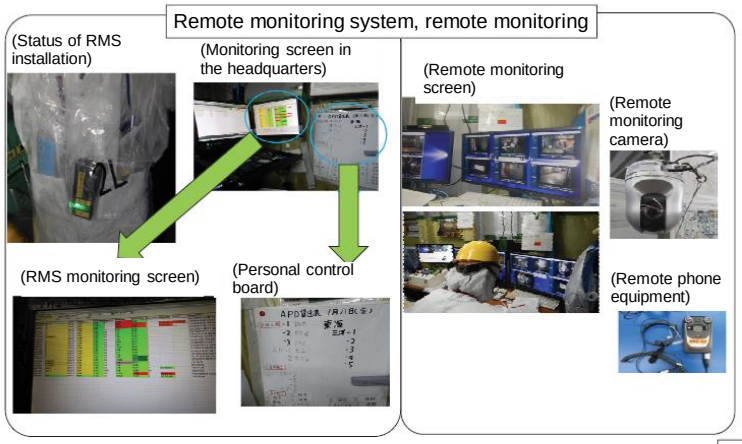
Good Practice Description

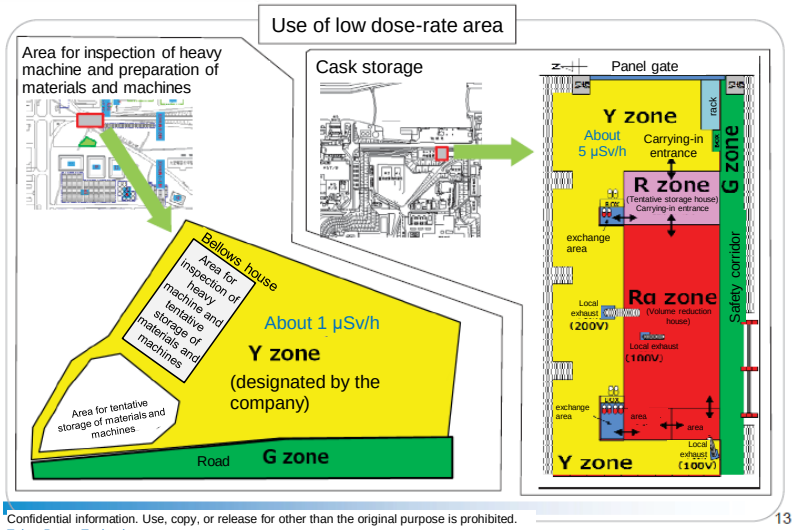
Before Implementation

Unit 2 reactor building 1FL, the main working area, had a high dose rate and there was a concern that people could be severely exposed to radiation if machines were moved manually.

Implementation Details

Various remote monitoring techniques shown below were used, and work construction methods to use, if possible, low-dose rate areas were employed.





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Location			Category		
Inside reactor building	(RB)	RB	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		6	Preventing spread of contamination	
			(7)	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-06

Title	Gantry steel frame assembling with prefabricated construction method
Work location	Seawater pump area => Around Unit 2 reactor building
Overview	Gantry steel frame was assembled in a seawater pump area where the dose ratio was low, and the gantry was moved to Unit 2 reactor building by using a super-carrier.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	3,907	2,189
		Person time (person-days)	--	--

Good Practice Description

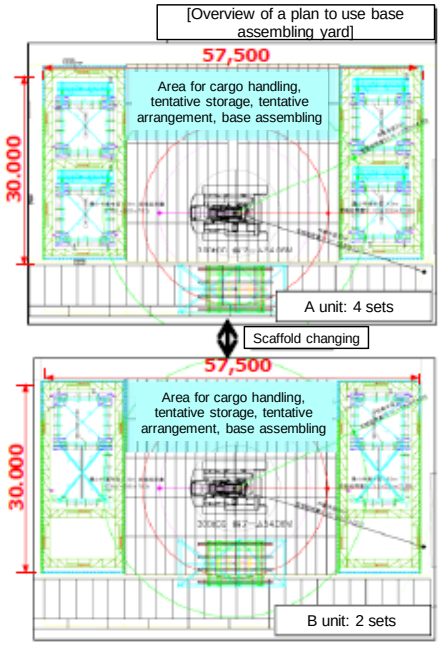
Before Implementation

The areas on the roof of the reactor buildings and around the buildings had a high dose rate and there was a concern about people's severe exposure to radiation.

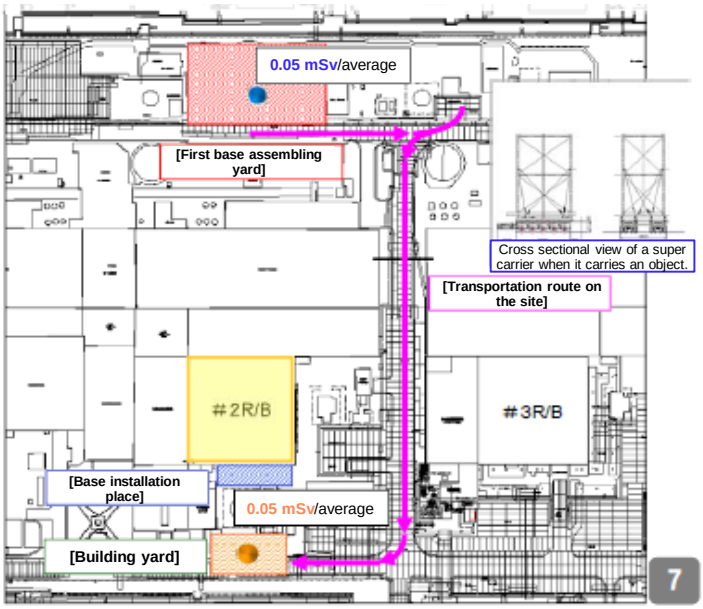
Implementation Details

Gantry steel frame was assembled in a low dose-rate area and the gantry was moved to Unit 2 reactor building, in order to reduce exposure during the assembling work.

Base assembling -> Transportation plan



Base steel frames are assembled in a low dose-rate area and carried to a reactor building where the frames are installed. This large unitization construction method can reduce unnecessary exposure.



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Location			Category	
Inside reactor building	(RB)	RB	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y		4	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			(7)	Other

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-07

Title	Unit 2 reactor building 1FL: Removal of obstacles to carry in machines in front of X-6
Work location	Unit 2 reactor building 1FL
Overview	Obstacles are removed to carry in machines in X-6 on Unit 2 reactor building 1FL.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

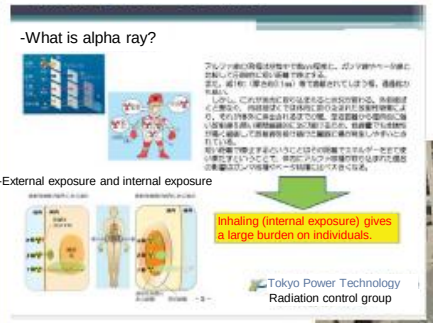
Before Implementation

Unit 2 reactor building 1FL, the main working area, was contaminated with alpha-ray emitting nuclide and it was necessary to completely prevent internal exposure.

Implementation Details

Training to wear and take off protective equipment and to experience contamination was conducted in advance to prevent body contamination and internal contamination due to taking off the protective equipment.

Implementation of table-top education



Implementation of contamination experiencing training

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	(RB)	RB/TB	1	Time	
Inside turbine building	(TB)		2	Distance	
R ZONE	R		(3)	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		6	Preventing spread of contamination	
			7	Other	

3

No.	01-08

Title	Tentative shielding before installation of retained-water discharging equipment
Work location	Unit 1 to 4 reactor buildings, turbine buildings, etc.
Overview	Training with mock-up, improvement of accessibility, and shielding of pathways were conducted before installation of retained-water discharging equipment in various places including Unit 1 to 4 reactor buildings, turbines, RW/B, etc.

Assessment ((qualitative)/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	2.0 and others (see below)	0.45 and others (see below)
	Person time (person-days)	--	--

Good Practice Description

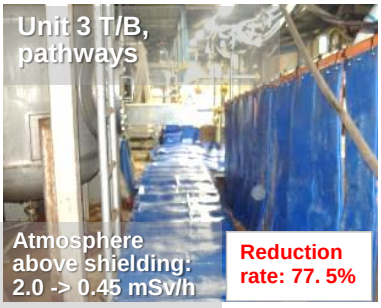
Before Implementation

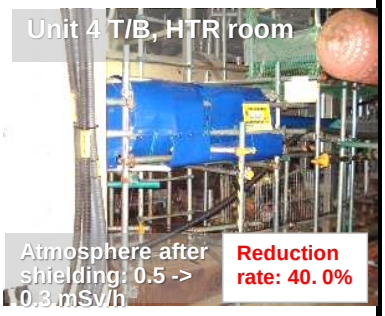
The work was conducted in various areas, some of which had a high dose rate.

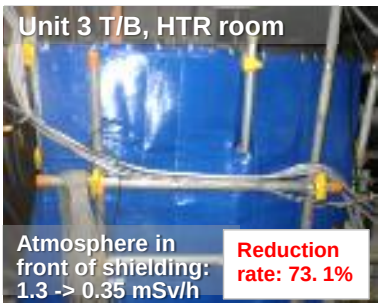
Implementation Details

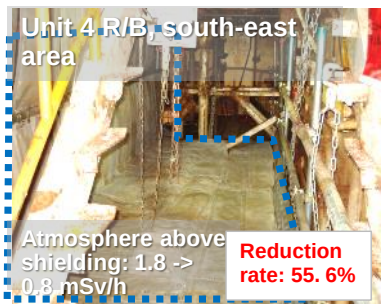
Shielding was installed mostly in work areas where a high risk of radiation exposure was expected. As a result, the dose rate was reduced by up to 78%. In addition, reduction in exposure for workers to walk on the pathways was also cared for.

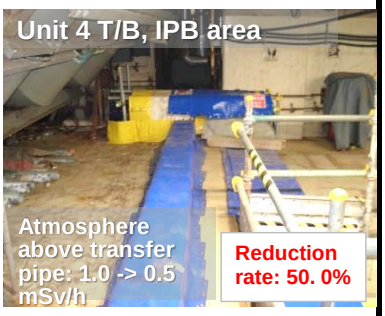
Shielding in work areas with high dose rate











Exposure reduction measures not only for work time but also for people to walk on pathways

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	(RB)	RB/TB	7	1 Time
Inside turbine building	(TB)			2 Distance
R ZONE	R			3 Shielding
Y ZONE	Y			4 Removing radiation source
G ZONE	G			5 Remote-control, robot operation
Other ( )	Z			6 Preventing spread of contamination
				(7) Other

No.	01-09

Title	Tentative shielding before installation of retained-water discharging equipment
Work location	Unit 1 to 4 reactor buildings, turbine buildings, etc.
Overview	Training with mock-up, improvement of accessibility, and shielding of pathways were conducted before installation of retained-water discharging equipment in various places including Unit 1 to 4 reactor buildings, turbines, RW/B, etc.

Assessment (qualitative/quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

Good Practice Description

Before Implementation The work was conducted in various areas, some of which had a high dose rate.

Implementation Details For higher passage efficiency, corridors were reviewed and newly installed and vertical ladders were switched to stairs.

Corridors and stairs were installed in the areas.

Installation of corridor

Review of corridor

Changing vertical ladder to stairs

Work efficiency and safety were improved.

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	(RB)	RB/TB	1	Time
Inside turbine building	(TB)		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y		4	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
		7	(7)	Other

No.	01-10

Title	Tentative shielding before installation of retained-water discharging equipment
Work location	Unit 1 to 4 reactor buildings, turbine buildings, etc.
Overview	Training with mock-up, improvement of accessibility, and shielding of pathways were conducted before installation of retained-water discharging equipment in various places including Unit 1 to 4 reactor buildings, turbines, RW/B, etc.

Assessment (qualitative/quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

Good Practice Description

Before Implementation	Increase of the work time was concerned because there were many kinds of work areas and because of poor workability.
Implementation Details	Training with mock-up was conducted in advance to shorten the work time and check the operation procedure.

Training was also conducted for removal of obstacles other than by using robots and for installation of pumps.

Mock-up facility outside 1F

Reduction in work time by training

Overview of muscle robot

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Location			Category		
Inside reactor building	RB	R	1	Time
Inside turbine building	TB		2	Distance
R ZONE	(R)		3	Shielding
Y ZONE	Y		(4)	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-11

Title	Decontamination of the entire building areas to reduce the dose rate
Work location	All 1F building areas
Overview	Dose rate was high in all 1F building areas, so decontamination was required to improve the working environment. We established the decontamination targets, designated the areas, took measures, such as decontamination/facing, and reduced the equipment.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

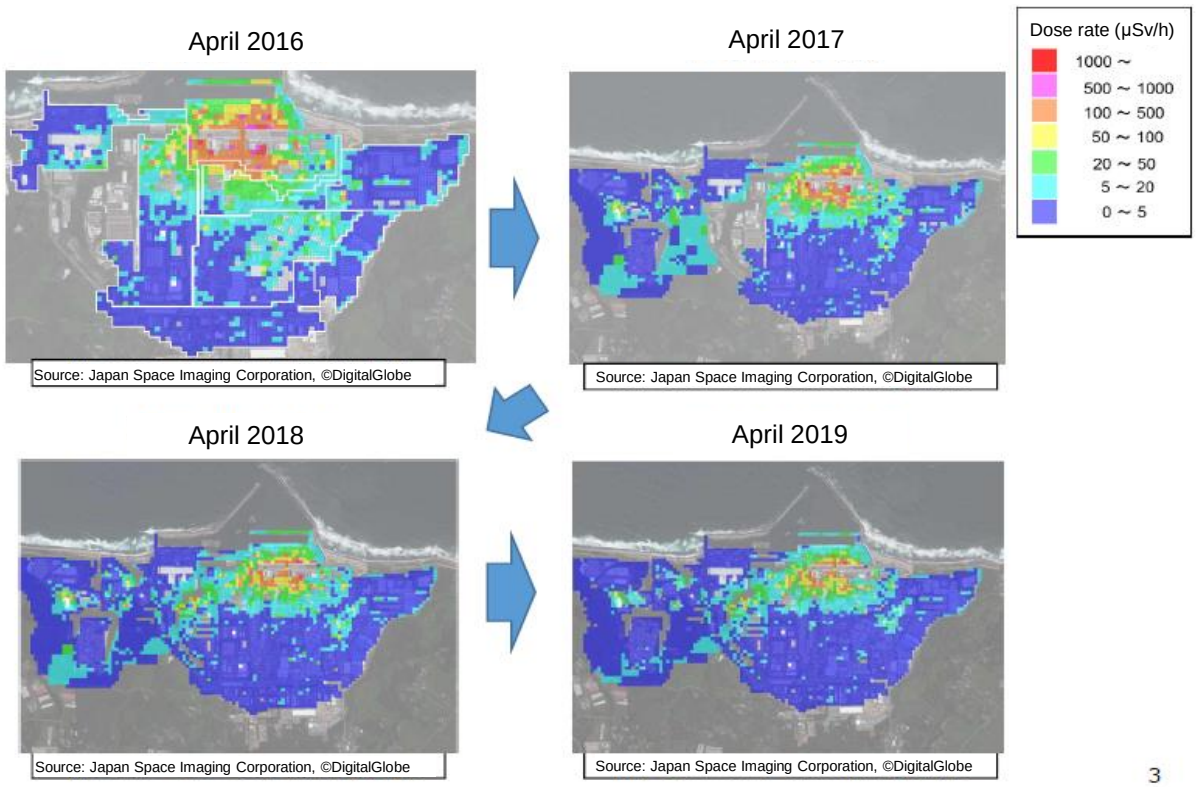
Good Practice Description

Before Implementation

Dose rate was high in all 1F building areas. Especially the areas around Units 1 through 4 were high, and dose rate reduction was urgent in order to reduce exposure.

Implementation Details

We established the decontamination targets, designated the areas, and took measures, such as decontamination/facing. As a result, 5μSv/h was achieved by the end of FY2015, excluding the areas around Units 1 through 4 and waste storage areas.



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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	R	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	(R)		3	Shielding	
Y ZONE	Y		(4)	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		6	Preventing spread of contamination	
			7	Other	

No.	01-12

Title	Decontamination of the entire building areas to reduce the dose rate
Work location	All 1F building areas
Overview	Dose rate was high in all 1F building areas, so decontamination was required to improve the working environment. We established the decontamination targets, designated the areas, took measures, such as decontamination/facing, and reduced the equipment.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

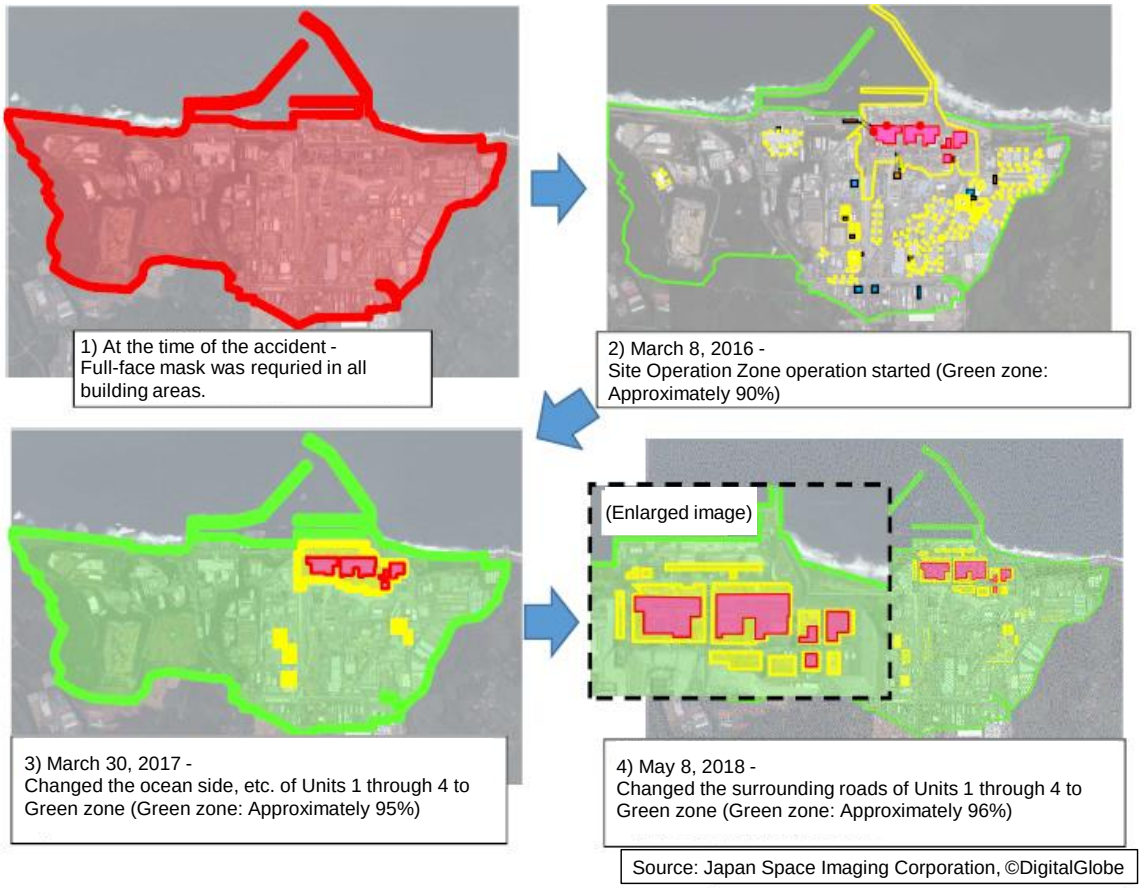
Good Practice Description

Before Implementation

Full-face mask was required for all 1F building areas, and workability was extremely poor.

Implementation Details

We established the decontamination targets, designated the areas, took measures, such as decontamination/facing, and reduced the protective equipment by area. Due to this, most of the building areas became G zones (excluding R/Y zones), and we were able to reduce protective equipment.



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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	RB	Y	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y	3	4	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

No.	01-13

Title	Unit 1/2 stack disassembly using robots
Work location	Outside of reactor building for Units 1 and 2
Overview	In order to disassemble the stacks for Units 1 and 2, we used remote-controlled disassembly robots. We also installed portable shields near the robot inspection areas to reduce exposure.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	0.7	0.01
	Person time (person-days)	--	--

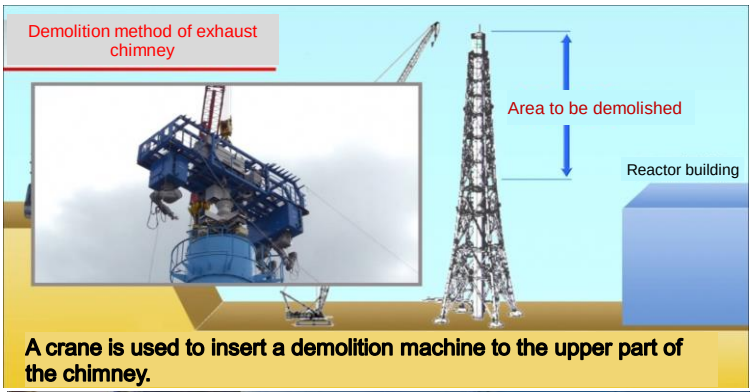
Good Practice Description

Before Implementation

The dose rate for the disassembly robot inspection areas was 0.7mSv/h or less.

Implementation Details

Portable shields enabled free movements depending on the operation, and additional shields were also freed.



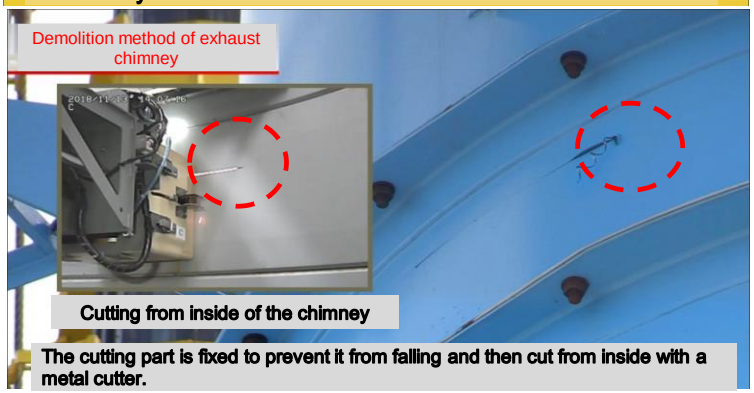


Photo: Portable shielding

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	RB	Y	3	1 Time
Inside turbine building	TB			2 Distance
R ZONE	R			3 Shielding
Y ZONE (○)	Y			4 Removing radiation source
G ZONE	G			5 Remote-control, robot operation
Other ( )	Z			6 Preventing spread of contamination
				7 Other

No.	01-14

Title	β ray shielding at the bottom of the tank due to disassembly of flange-tank
Work location	Flange-tank installation areas
Overview	We have manufactured remote-controlled coating equipment in order to contain the contamination produced during the disassembly of 17 flange-tanks, and have been containing contamination during disassembly.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	5.71	0.90
	Person time (person-days)	--	--

Good Practice Description

Before Implementation

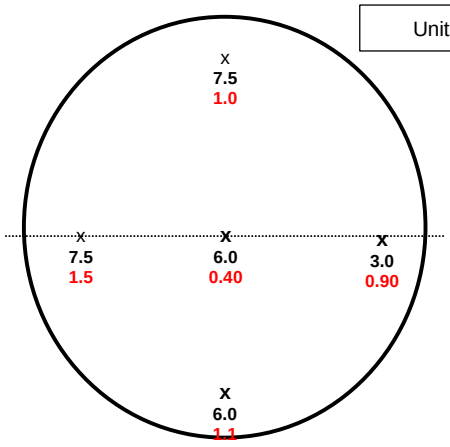
B+γ rays were high at the bottom of the tanks, and β ray exposure became an issue.

Implementation Details

We installed rubber boards at the bottom of the tanks and plywood panels + aluminum boards on the sides to block β rays.

Dose equivalent rate measurement result within C10 tank
(Measurement location: 50cm from the side board, 1.2m from the floor)
Black: Before implementation Red: After implementation

Unit: mSv/h



Measure: Installation of shielding
- Install shielding rubber at the bottom of the tanks.
- Install plywood panels + aluminum boards on the sides of the tanks

Reduction effect (β+γ ray dose equivalent rate average)
Before implementation: 5.71 mSv/h
After implementation: 0.90mSv/h: 84.2% reduction

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Location			Category		
Inside reactor building	RB	Y	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE (○)	Y		4 (○)	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		6	Preventing spread of contamination	
			7	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-15-1

Title	Utilization of laser decontamination when disassembling flange-type tanks
Work location	1F building tank yard
Overview	We are performing laser decontamination in order to reduce β ray exposure when disassembling flange-type tanks.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	179.7 (β ray)	127.0 (β ray)
		Person time (person-days)	--	--

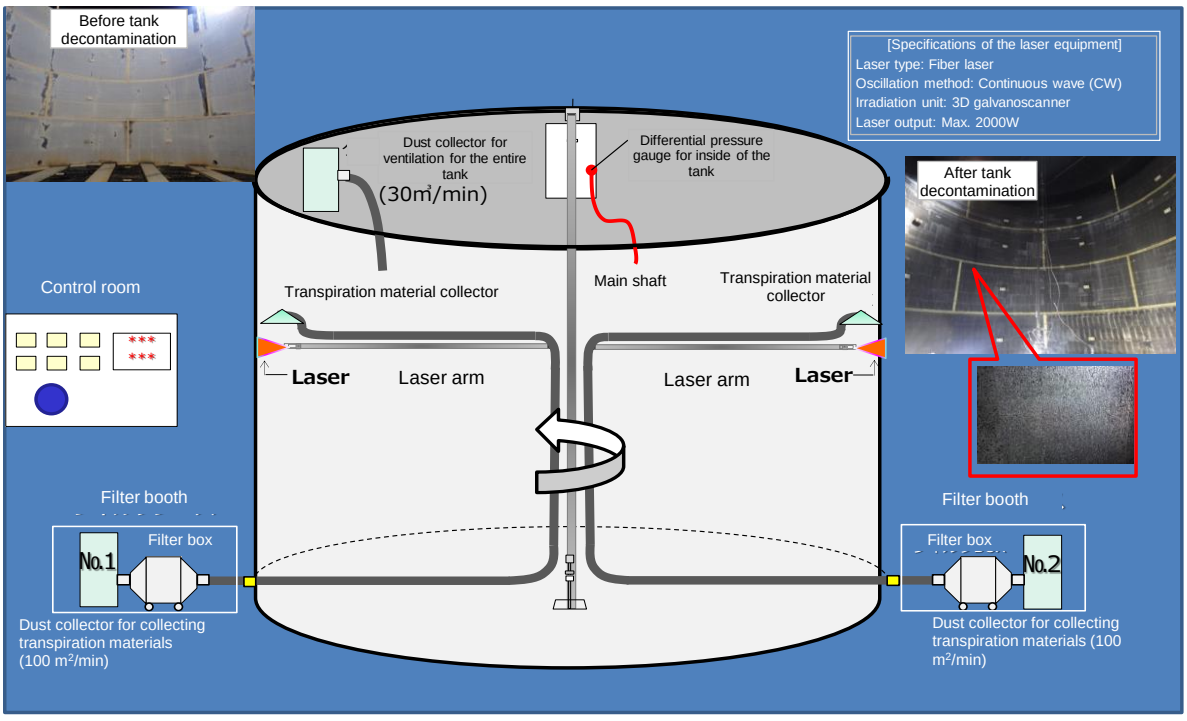
Good Practice Description

Before Implementation

Inside of flange-tanks was contaminated with nuclide emitting high-energy β rays, so β ray exposure was an issue when disassembling tanks.

Implementation Details

We used modified laser decontamination equipment to decontaminate the entire tanks in order to reduce exposure to β rays adhered to the surface of the tanks with the aim of reducing exposure and preventing contamination expansion during tank disassembly.



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Location			Category	
Inside reactor building	RB	Y	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE (○)	Y		4 (○)	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-15-2

Title	Utilization of laser decontamination when disassembling flange-type tanks
Work location	1F building tank yard
Overview	We are performing laser decontamination in order to reduce β ray exposure when disassembling flange-type tanks.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	179.7 (β ray)	127.0 (β ray)
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

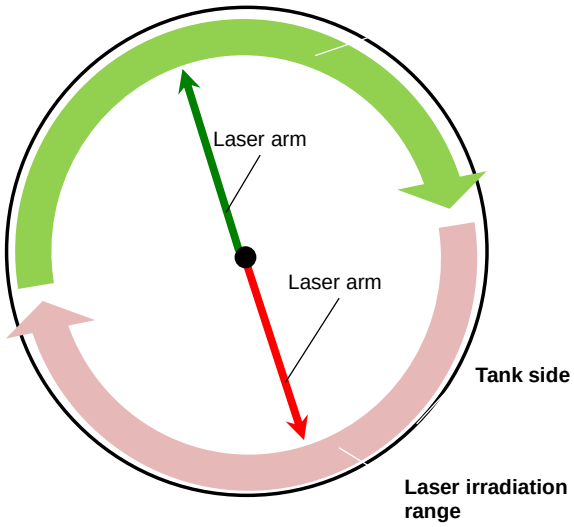
Inside of flange-tanks was contaminated with nuclide emitting high-energy β rays, so β ray exposure was an issue when disassembling tanks.

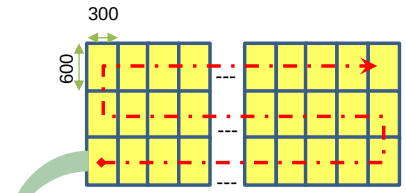
Implementation Details

We used modified laser decontamination equipment to decontaminate the entire tanks in order to reduce exposure to β rays adhered to the surface of the tanks with the aim of reducing exposure and preventing contamination expansion during tank disassembly.

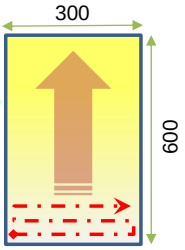
➢Laser irradiation to the tank side was 1 block (600×300mm). Irradiate => move => irradiate => move was repeated.

➢There are 2 laser arms, and laser irradiation to all of the tank sides is made possible by each laser rotating by approximately 180 degrees.





Laser irradiation order



Laser irradiation per block

Number of blocks per tank: Approximately 2,500

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	Y	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	(Y)		4	Removing radiation source	
G ZONE	G	6	5	Remote-control, robot operation	
Other ( )	Z		(6)	Preventing spread of contamination	
			7	Other	

No.	01-16

Title	Remote-controlled contamination containment in disassembly of flange-tanks
Work location	Flange-tank installation areas
Overview	We have manufactured remote-controlled coating equipment in order to contain the contamination produced during the disassembly of 17 flange-tanks, and have been containing contamination during disassembly.

Assessment (qualitative/ (quantitative))	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	24.89/tank	0.00/tank
	Person time (person-days)	2	2

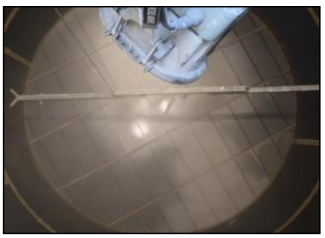
Good Practice Description

Before Implementation

B+γ rays were high at the bottom of the tanks, and β ray exposure became an issue.

Implementation Details

For coating the inner surface of the tanks with paint with the aim of shielding β rays and preventing dust, we used the special coating equipment for flange-tanks to contain contamination and also reduced man-powered work as much as possible.



Exposure reduction effect

*Average geometric mean dose rate in tanks before coating (β + γ rays)

2.54mSv/h

- In case of man-powered work (2 workers)

2.54mSv/h×7h x 2 people x 0.7 = 24.89 people/mSv

*30% reduction by wearing Anorak is considered.

- In case of unmanned work using spraying equipment

Actual radiation exposure dose between the installation and removal of the spraying equipment

β + γ 0.00 people/mSv

Per tank: Reduction of 24.89 people/mSv

Spraying completed

■ Achievements

(1) Reduction measures finalized in ALARA and other meetings are being implemented as common measures for radiation workers and site workers.

(2) The relay yard, which had a relatively low dose rate outside the high dose work areas, could be used and this was effective in reducing exposure dose.

■ Future challenges

(1) Even with rotating shifts, worker allocations remain uneven due to differences in the skills and experience levels of individual workers. As a result, dose exposures are distributed unevenly among workers. → Continue implementing worker allocation plans

(2) Scheduled work could not be completed due to many equipment failures, resulting in unexpected increases in exposures.

(3) Although worker movement flows were decided, there were a number of cases where workers did tasks under staff's instruction not in line with those flows and had to move through areas with high dose rates during an evacuation time. → Continue managing movement

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Location			Category		
Inside reactor building	RB	Y	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	(Y)		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		(6)	Preventing spread of contamination	
			7	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-17

Title	Unit 1/2 stack disassembly using robots
Work location	Outside of reactor building for Units 1 and 2
Overview	In order to disassemble the stacks for Units 1 and 2, we used remote-controlled disassembly robots. We also installed portable shields near the robot inspection areas to reduce exposure.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

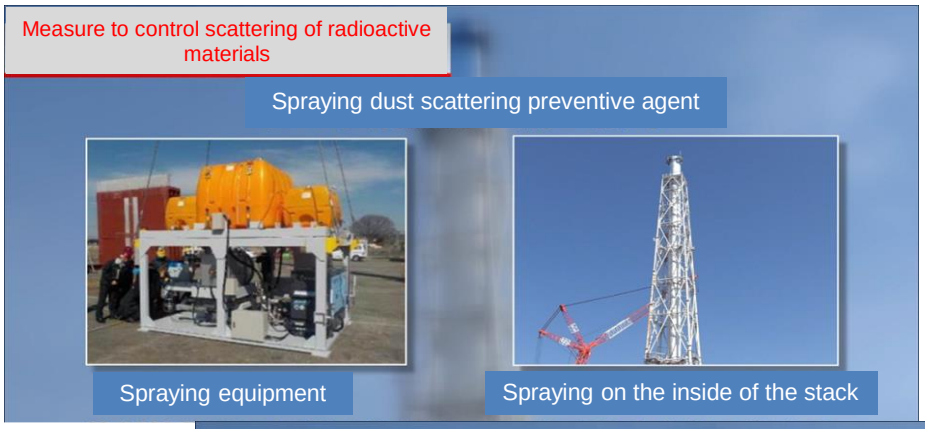
Good Practice Description

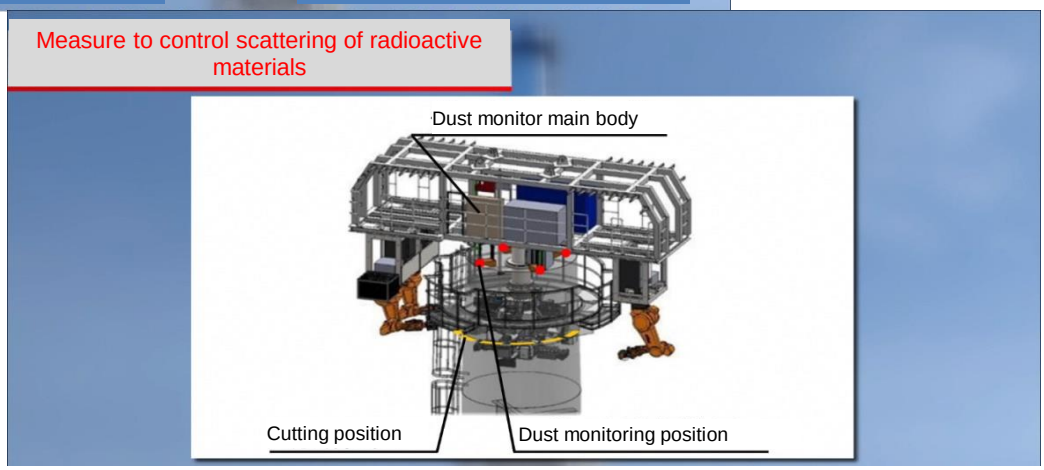
Before Implementation

Scattering of radioactive materials was a concern when cutting/disassembling stacks.

Implementation Details

In order to cut/disassemble stacks, we coated the inside with dust scattering preventive agent in advance and monitored the dust concentration at all times during the cutting work.





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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	Y	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	(Y)		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	Z		(6)	Preventing spread of contamination	
			7	Other	

No.	01-18

Title	Unit 1/2 stack disassembly using robots
Work location	Outside of reactor building for Units 1 and 2
Overview	In order to disassemble the stacks for Units 1 and 2, we used remote-controlled disassembly robots. We also installed portable shields near the robot inspection areas to reduce exposure.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

Increase in the work time was a concern when cutting/disassembling stacks.

Implementation Details

In order to cut/disassemble stacks, we performed thorough mock-up training to master the skills.

Scene from the mock-up training in Hirono Plant

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Location			Category		
Inside reactor building	RB	Z	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	(Z)		6	Preventing spread of contamination	
			(7)	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-19

Title	Visualization of exposure / Visualization of contamination
Work location	Naraha-machi community center, others
Overview	With the aim of giving exposure/contamination simulation to workers on 1F, we made “Visualization of exposure” and “Visualization of contamination” videos for exposure reduction training.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

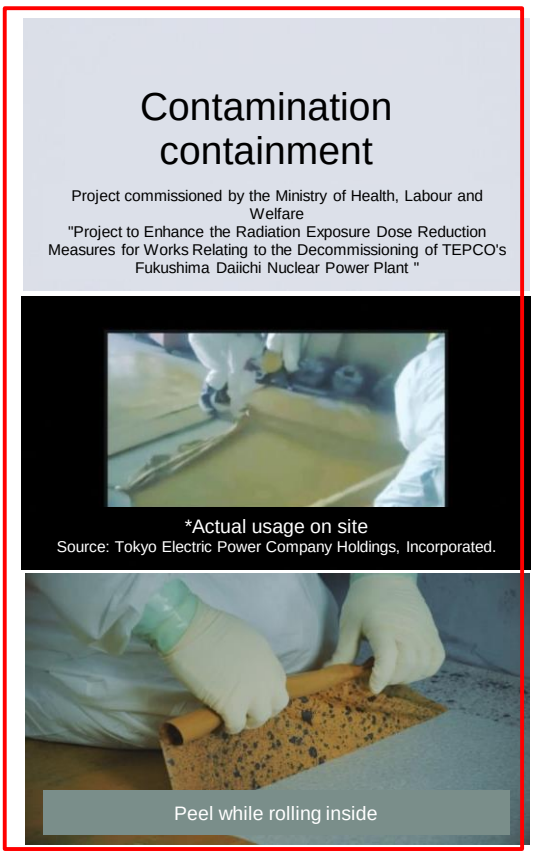
Before Implementation

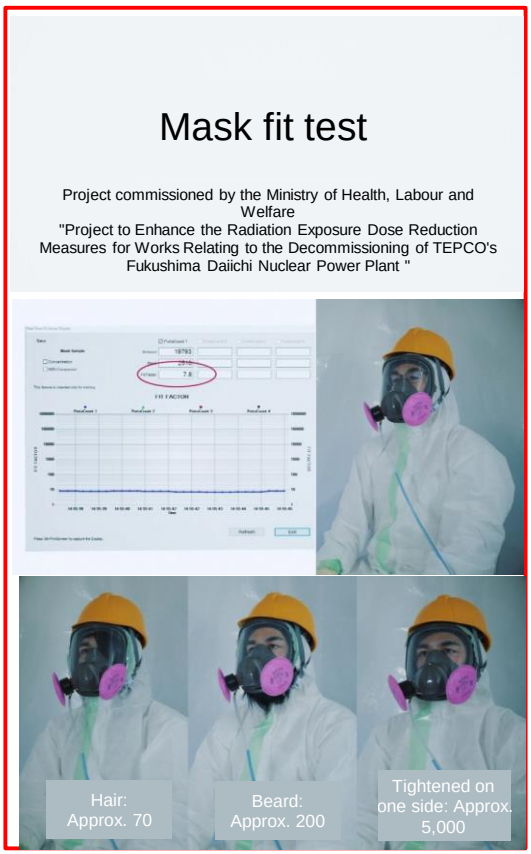
Issues in the field that arose along with the progress of the decommissioning work of Fukushima Daiichi Nuclear Power Plant were difficult to comprehend.

Implementation Details

We made “Contamination containment” and “Mask fit test” videos for exposure reduction training.

Contamination containment / Mask fit test





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Location			Category		
Inside reactor building	RB	Z	1	Time	7
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	(Z)		6	Preventing spread of contamination	
			(7)	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-20

Title	Exposure simulation
Work location	Naraha-machi community center, others
Overview	With the aim of giving exposure/contamination simulation to workers on 1F, we proposed/established the “Visualization of exposure” system for exposure reduction training.

Assessment (qualitative/quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

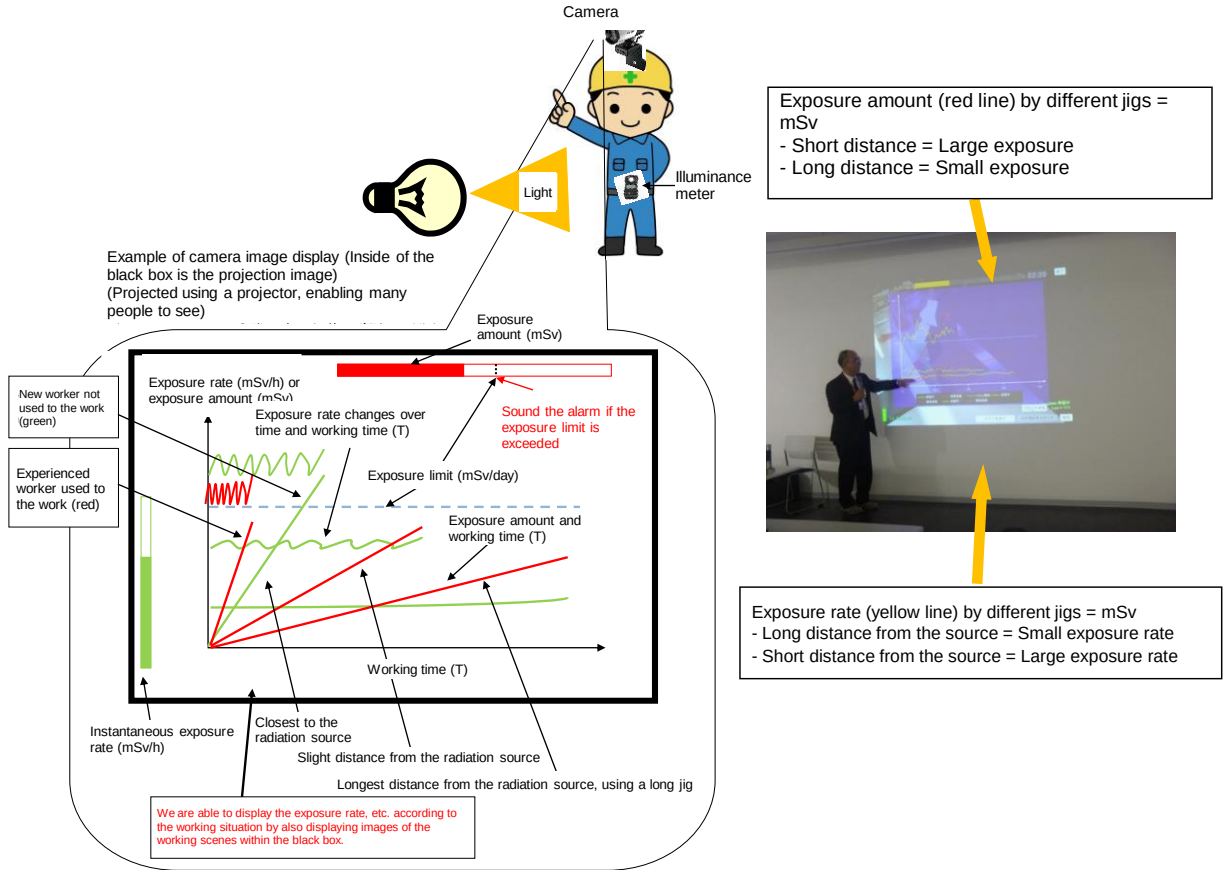
Before Implementation

There was no video (system) to “simulate exposure” in exposure reduction training in Japan.

Implementation Details

We proposed/established the “system to simulate exposure” for exposure reduction training.

Created simulation system to show that light = radiation source



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Location			Category		
Inside reactor building	RB	Z	1	Time	
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	(Z)		6	Preventing spread of contamination	
			(7)	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

No.	01-21

Title	Remote monitoring system (RMS) utilization (1)
Work location	Main processing building, etc.
Overview	Although RMS is effective in reducing exposure for managing personnel, etc., conventional RMS was large/heavy and restricted the installation site, etc. However, we developed compact/light RMS and also improved the usability.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

Before Implementation	Although we were using RMS to reduce exposure, the equipment was large/heavy, etc. and could not be easily installed.
Implementation Details	We developed compact/light RMS and used in place of the conventional RMS. As a result, we confirmed that it was easy to install/remove and was effective in reducing exposure.

- Due to having weight and requiring installation space, it is not easy to install
- Wireless APD battery exhaustion / Lack of a function to enable a user to check the radiation exposure dose by himself
- Size of the communication equipment main body
- Need to establish networks separately for APD and communication equipment
- Software/equipment display in English

One set consists of one monitoring PC and 10 units of information

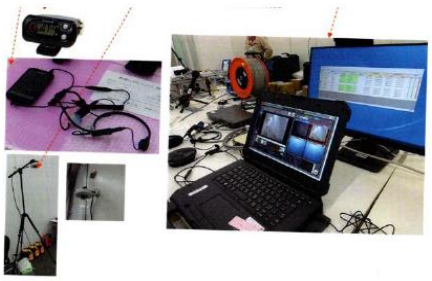
A dosimeter operates for approximately 4 months on one battery. Information terminals are charged using special stands.

A user can check his own radiation exposure dose with an information terminal on site.

Wireless communication of various devices is uniformly established through Wi-Fi.

Equipment installed on site (cameras/relays) has dustproofing and waterproofing

Support system in Japanese



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Location			Category		
Inside reactor building	RB	Z	1	Time	7
Inside turbine building	TB		2	Distance	
R ZONE	R		3	Shielding	
Y ZONE	Y		4	Removing radiation source	
G ZONE	G		5	Remote-control, robot operation	
Other ( )	(Z)		6	Preventing spread of contamination	
			(7)	Other	

Good Practices in Radiation Exposure Dose Reduction Measures

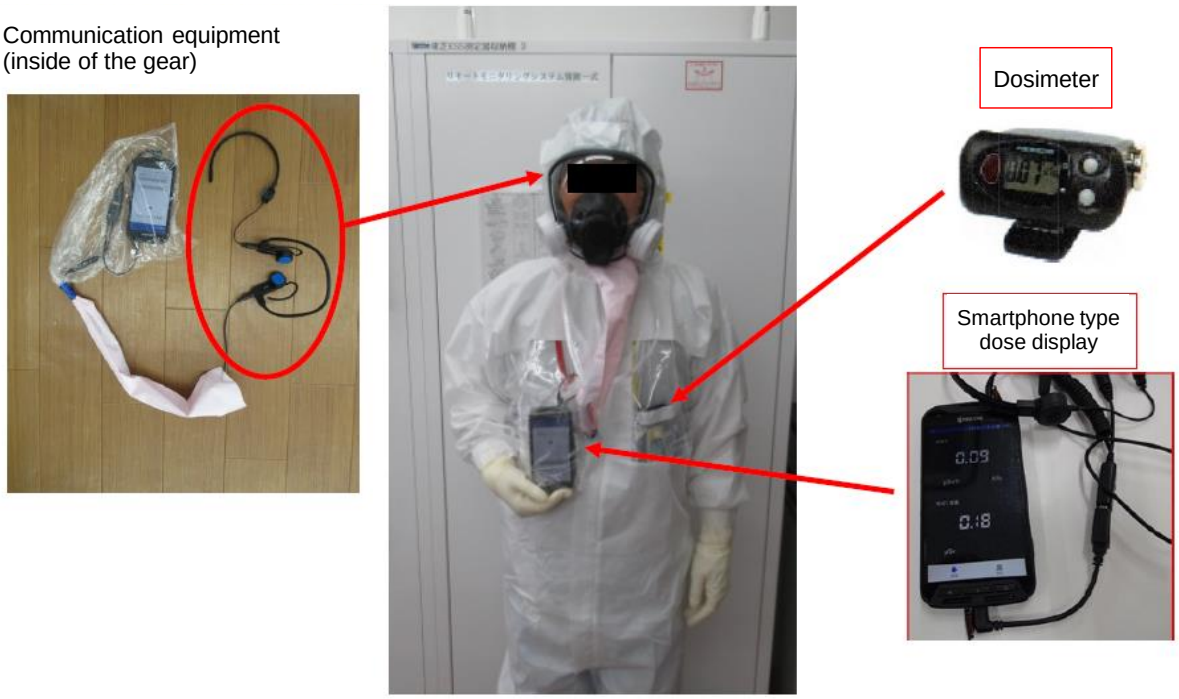
No.	01-22

Title	Remote monitoring system (RMS) utilization (2)
Work location	Main processing building, etc.
Overview	Although RMS is effective in reducing exposure for managing personnel, etc., conventional RMS was large/heavy and restricted the installation site, etc. However, we developed compact/light RMS and also improved the usability.

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

Good Practice Description	
Before Implementation	Although we were using RMS to reduce exposure, the equipment was large/heavy, etc. and could not be easily installed.
Implementation Details	We developed compact/light RMS and used in place of the conventional RMS. As a result, we confirmed that it was easy to install/remove and was effective in reducing exposure.

Dosimeter and dose display (smartphone type) are equipped on the chest, and communication device is equipped on the inside of the gear.



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On-site headquarters

Entrance area for carrying-in large objects

A camera is installed for monitoring from a monitor at driver's seat.

Shielded heavy machine (backhoe)

Shielded fork lift

Shielded carrier for high-place work

Mobile shielded carrier

Good Practices

Issued in January, 2020

Commissioned by the Ministry of Health, Labour and Welfare

"FY2019 Project to Enhance the Radiation Exposure Dose Reduction Measures for Works Relating to the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant"

Assignee: Japan Environment Research Co., Ltd