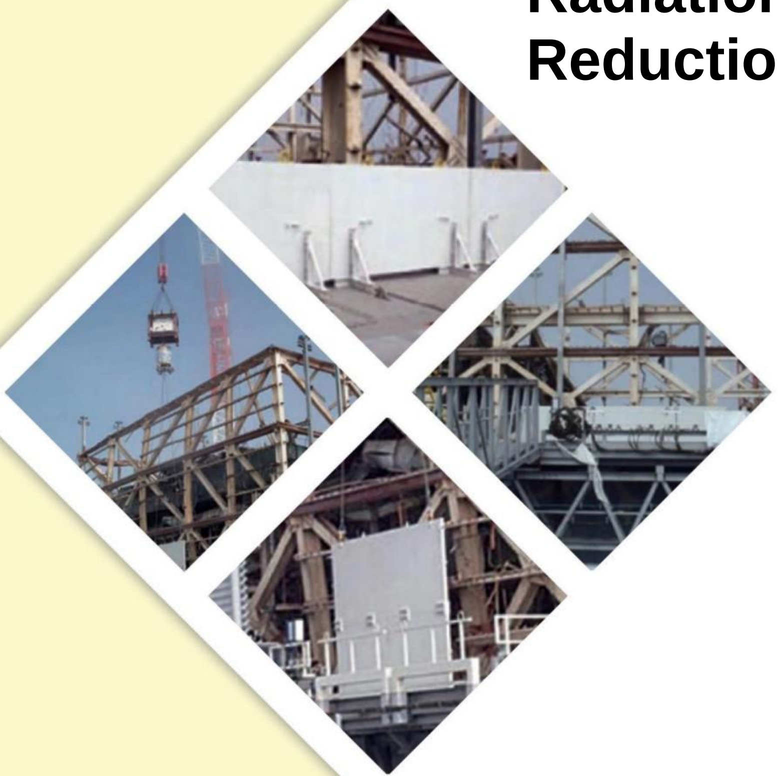
Commissioned by the Ministry of Health, Labour and Welfare

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

Good Practices in Radiation Exposure Dose Reduction Measures



Issued in March 2021

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1

Fundamental knowledge on radiation and radioactivity

(1) Units of radiation and radioactivity

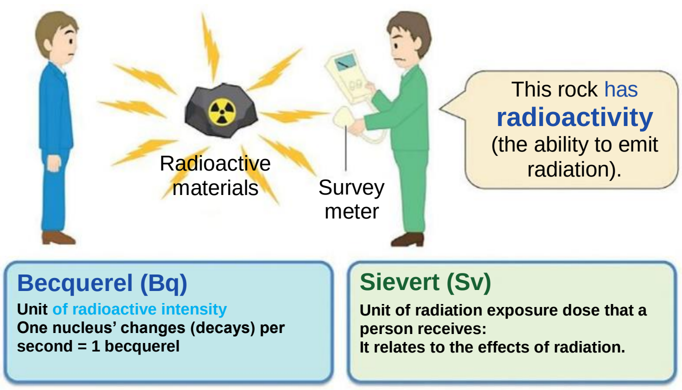
Radioactive materials emit radiation to the surroundings. Radiation includes alpha (α) rays, beta (β) rays, gamma (γ) rays, and others. Gamma rays have strong penetrating power and are the primary cause of external exposure. Alpha rays are known to be helium nuclei composed of two protons and two neutrons, which are ejected at high velocity. Beta rays are electrons emitted from atomic nuclei. Atomic nuclei in an unstable state, with high energy, emit γ-rays immediately after emitting α-rays or beta-rays for becoming stable state.

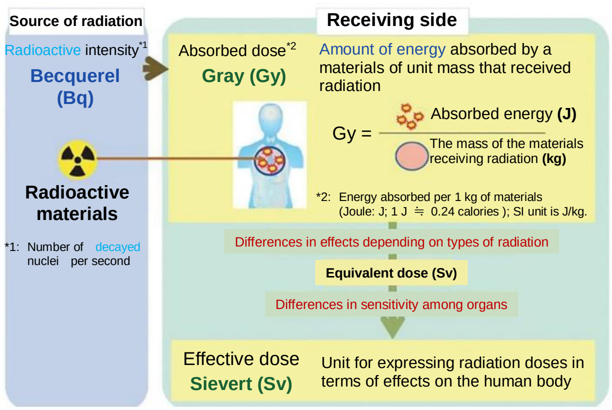
The table below summarizes the units of radiation exposure. Roughly speaking, units of measurement of radiation are divided into two types: the absorbed dose, which represents the energy absorbed by a materials by receiving radiation; and the equivalent dose and effective dose, which represent the effects of radiation on human bodies. An absorbed dose is a physical quantity used for both humans and objects. An effective dose is a unit for expressing stochastic effects, such as human cancer and genetic effects.

		Unit	Definition
Unit of radioactivity		Becquerel Bq	The number of radioactive decays per second (number/second).
Unit for measuring radiation exposure	Absorbed dose	Gray Gy	The amount of radiation energy absorbed in matter. A dose of 1 Gy corresponds to 1 joule (J) of energy absorbed by 1 kilogram (kg) of matter.
	Equivalent dose	Sievert Sv	The dose for each tissue or organ, measured in order to evaluate the effects of radiation exposure on the tissue or organ. Equivalent dose = absorbed dose × radiation weighting factor
	Effective dose	Sievert Sv	The value obtained by multiplying the equivalent dose of an organ or tissue by the tissue weighting coefficient (due to differences between organs and tissues). Dose for evaluating the stochastic effect of cancer or other diseases on the entire human body: Effective dose = Σ (equivalent dose × tissue weighting factor)

Radioactivity is the ability of a radionuclide to transform into another nucleus (called disintegration or decay). The measured value is expressed in the unit called Becquerel (Bq). Radioactive materials are materials with radioactivity. For example, if the radioactivity of a substance weighing 2 kg is 100 Bq, we can say that its specific activity is 50 Bq / kg.

Expressions such as "It was contaminated with **radioactivity**" or "**radioactivity** was released" are incorrect. The correct representation is that "Radioactive **materials** were released. The **radioactivity** of the released **materials** is 100 Bq."





Material provided by the Ministry of the Environment of Japan; "BOOKLET to Provide Basic Information Regarding Health Effects of Radiation (2020)".

(2) Principles for Radiation Exposure Protection

Reducing external exposure

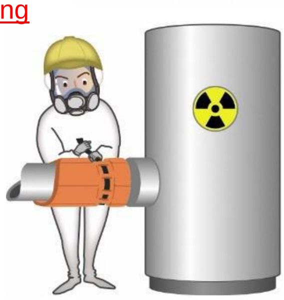
To reduce external exposure, it is important to understand the following four principles of radiation exposure protection.

Principle 1 Remove radioactive materials

Move radioactive materials or wash them out (flush them) from the inside of piping.

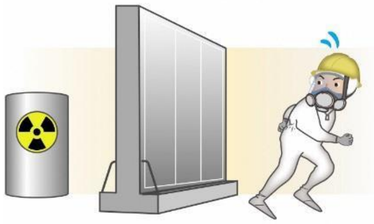
Principle 3 Install shielding

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



Principle 2 **Maintain sufficient distance from radiation**

If possible, move away from the radiation source. Do not go any closer to it than required. (Also remember where the waiting areas are.)



Principle 4 Reduce working time

Make sufficient preparations before conducting work, such as discussing the procedures involved or inspecting tools, so that work proceeds smoothly.

Preventing internal exposure

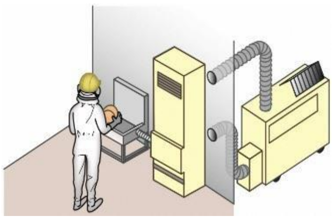
To prevent internal exposure, it is important to wear the required personal protective equipment so that radioactive materials are not taken into the human body. Measures must also be put in place to prevent radioactive materials from being blown around in the air, and to contain (and limit) any contamination and stop it spreading (dispersing).

Principle 1 Clearly outline contamination zones

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

Principle 3 Use equipment and materials

For work in areas where there is a risk of dust being blown around, use temporary shelters or exhaust fans with filters.



Principle 2 Wear protective equipment

Wear the required personal protective equipment. Fit the respiratory protective equipment properly, so that there are no leaks.

Principle 4 Move to safety

When leaving the working area, check and remove any radioactive contamination on the body. Before removing protective equipment (masks, protective clothing, gloves, etc.), first wipe them off to prevent radioactive materials being taken into the body. Be sure to decontaminate them, and then remove them when undergoing the contamination checks. In the event of injury, move to an uncontaminated area immediately.

2
1F Site Operation Zone Control

(1) 1F site operation zone status

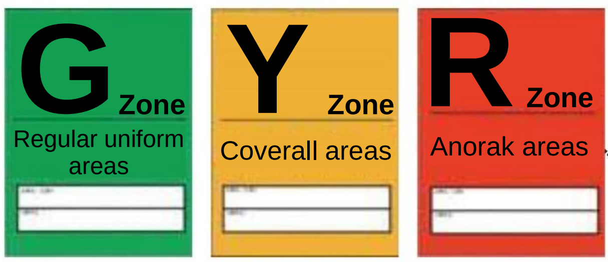
Controlled zones are classified into the following three classes, according to contamination level.

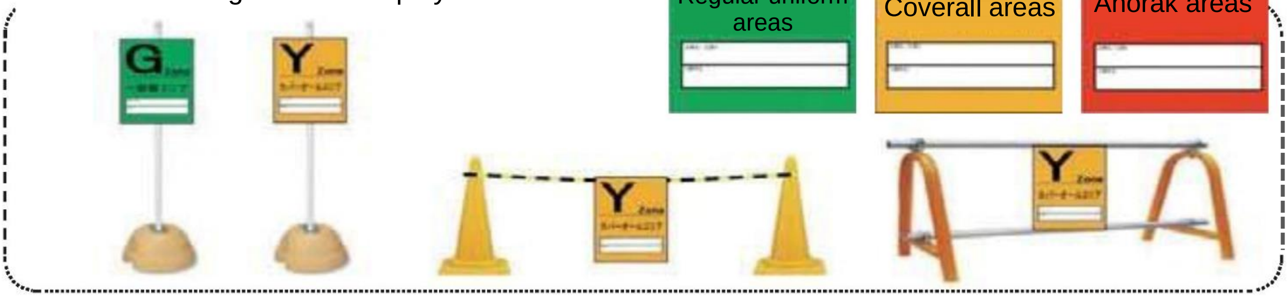
<table>
<tr><th colspan="2">Zone</th><th>Protective Equipment</th></tr>
<tr><td colspan="2">Red zone (Anorak areas)
• Inside Units 1 to 3 reactor buildings
• Peripheral areas with retained water of Units 1 to 4 buildings</td><td>• Full-face mask
• Anorak
• Work boots (for R zone)
• Helmet (for R zone)
• Cotton gloves + rubber gloves</td></tr>
<tr><td rowspan="2">Yellow zone (Coverall areas)</td><td>• Inside buildings that include water treatment facilities (such as desalination units, multi-nuclide removal facilities)
• Work in areas around tanks that contain concentrated salt water or strontium-treated water*1, and work that involves the handling of transport lines to tanks.</td><td>• Full-face mask
• Coverall
• Work boots (for Y zone)
• Helmet (for Y zone)
• Cotton gloves + rubber gloves</td></tr>
<tr><td>• Around Units 1 to 4 buildings
• Specified as required to suit work environment (such as inside Units 5 and 6 buildings, parts of storage areas for high-radiation exposure dose rubble)</td><td>• Half-face mask
• Coverall
• Work boots (for Y zone)
• Helmet (for Y zone)
• Cotton gloves + rubber gloves</td></tr>
<tr><td colspan="2">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 Units 1 to 4 buildings and slope faces of Units 1 to 4.</td><td>• DS2 mask
• Site clothing, regular work clothing*2
• Work boots (for G zone)
• Helmet (for G zone)
• Cotton gloves + rubber gloves, or work gloves</td></tr>
<tr><td colspan="2">• Inside important anti-seismic buildings and inside rest area</td><td></td></tr>
</table>

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

(Taken from the website of Tokyo Electric Power Company Holdings, Inc.)

For easy identification of different zones, such as Yellow and Green zones, any of the signs shown on the right will be displayed.





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

[Ref.] Zone map (as of December 2020*4)

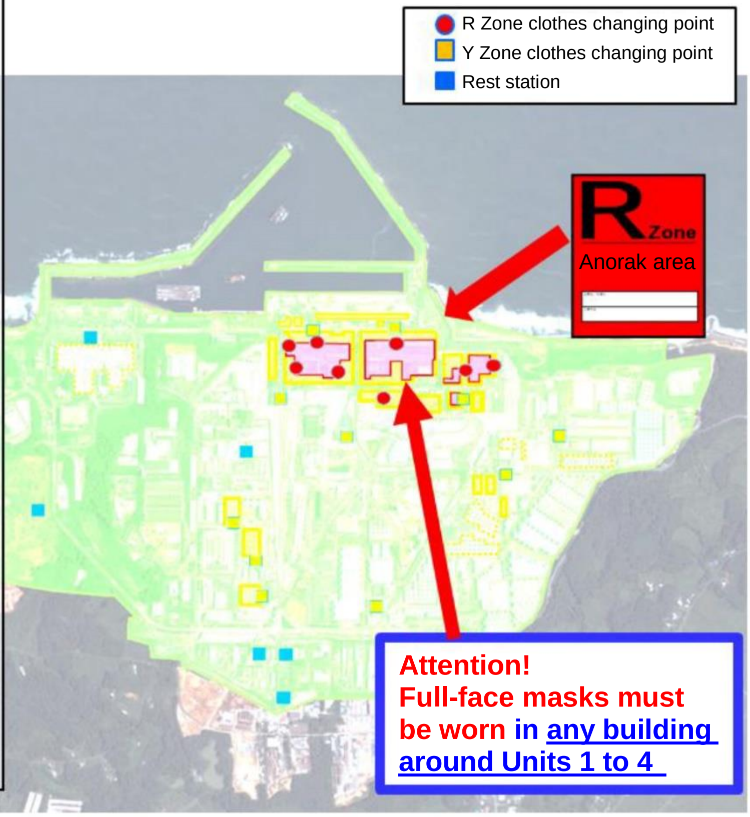
R zone	[Anorak area]*1
Y zone	[Coverall area]*2
G zone	[Regular work clothing area]*3

*1: **R Zone:** Inside Units 1 to 3 reactor buildings, and areas with stored water around Units 1 to 4 turbine buildings and surrounding buildings.

***2:** **Y zone** shown in dotted yellow lines is for when working with concentrated salt water or **work related to contamination** and requires **G zone equipment** during patrols or when conducting site surveys for creating work plans. When performing work in high dust concentrations (such as demolishing buildings) in the G zone, or working with concentrated salt water or work related to tank transfer lines, those areas will be temporarily specified as the **Y zone**.

*3: In addition to the **G zone** on the map, also applies to some areas of the common pool building 2F and 3F.

*4: Be sure to check the latest updates.



(Material provided by Tokyo Electric Power Company Holdings, Inc, in March 2021.)

3

Good Practices

Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
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	No.	02-01
				7	Other		

Title	Shielding for foundation improvement works in areas with high dose rates			
Work location	Peripheral areas of Unit 1 building and Units 1 and 2 exhaust stacks			
Overview	In order to reduce the exposure from high dose rate radiation sources of Units 1 and 2 exhaust stacks, engineering measures (installation of a shielding wall) and management measures (monitoring with camera equipment) were taken.			
Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	933.5	428.6
		Person time (person-days)	–	–
Good Practice Description				

Before implementation: The air dose rates were high around the Unit 1 reactor building and the Units 1 and 2 exhaust stacks. This caused concern about a large amount of exposure.

Details of measures: As an engineering measure to reduce the exposure of foundation improvement workers, shielding walls were installed, considering the directions of the radiation sources.

As a management measure to reduce the exposure of on-site staff members, cameras were installed to monitor existing shielding equipment.

- Engineering measures (installation of a shielding wall structure, considering the radiation source)

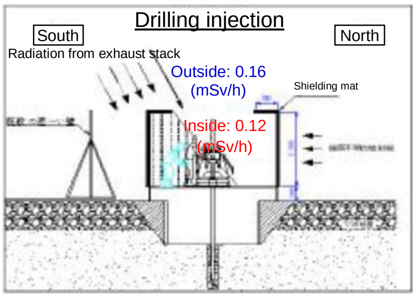


Fig. 1 Shielding with steel covering

Reduction impacts from exhaust stack

Pic. 1 Shielding equipment

• A 16 mm thick steel plate (shielding effectiveness: 50%)

- Management measures (cameras were installed to monitor existing shielding equipment)

Pic. 2 On-site monitoring staff room (near the site) (Dose rate inside is one-tenth of that measured outside)

Pic. 3 Four fixed cameras are managed on one monitor (management load, onsite: monitoring room = 6:4)

Edited by Kajima Corporation

Location				Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	TB		1 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	No.	02-02
					7	Other		

Title	Remote operation system: integration of remote operated heavy machines, equipment, and communication
Work location	Unit 3 turbine building rooftop and Units 3 and 4 service area 2F
Overview	In order to remotely collect and remove high-dose rubble on the roof of Unit 3 T/B, we constructed a remote operation system that integrates a Karuwaza suction device, a robot SAM-installed BH, a mobile camera, and a remote operated 600t crawler crane.

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

Good Practice Description

Remote operation room (Units 3 and 4 SB 2F)

Mobile camera, SAM-installed BH

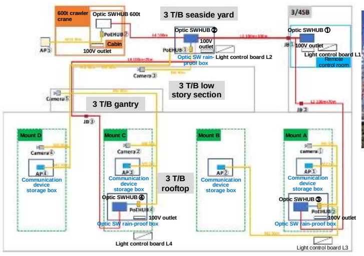
Wireless LAN_AP, fixed camera

■ Outline description

We constructed a system to remove high-dose rubble on the roof of Unit 3 T/B remotely. The system was planned by predicting the congestion of wireless LAN and based on survey results on wireless communication. In order to operate multiple remote operated devices, including newly developed ones and existing ones, we integrated their systems, combining wireless, optical, and LAN networks.

■ Effects of introduction

The introduced wireless communication and stable remote operation capability, and the availability of high-resolution images throughout the working areas, has improved the rubble removal efficiency and reduced exposure dose. The off-site training using mockups helped workers to master remote operating devices and systems, and shortened on-site maintenance time.



Communication network

Suction equipment

■ Composition of remote operation system

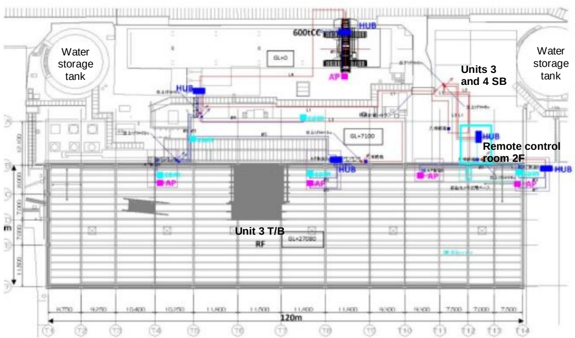
[Remote operation room] Monitors (18 units), PCs (7 units), controllers (5 units)

[Wireless communication] Wireless LAN (2.4/5 GHz), 433 MHz specified low power radio equipment

[AP] Wireless LAN_AP (8 units), 433 MHz antenna (4 units)

[Wired network] Optic 680 m, LAN 600 m, SW (11 units)

[Monitoring cameras] Network cameras (28 units)



3T/B Concept of remote operation system

Edited by Taisei Corporation

Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	TB	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	No.	02-03
				7	Other		

Title	Mobile camera equipment for remote operated monitoring			
Work location	Unit 3 turbine building rooftop			
Overview	Mobile camera equipment for remotely operating and monitoring the suction device and the robot SAM-installed backhoe used to collect and remove high-dose rubble on the roof of Unit 3 T/B			
Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	–	–
		Person time (person-days)	–	–
Good Practice Description				

■ Outline description

In remote-controlled works, the work efficiency depends on the images captured by monitoring cameras. However, since the roof of the Unit 3 T/B is spacious, fixed monitoring cameras may cause problems, due to restrictions on the number of cameras to be installed, blurring during zooming, and deterioration of image quality.

For this reason, we have developed wireless, remote-controlled and mobile camera equipment that can get close to and shoot a target work site at the optimum angle of view.


Rubble on Unit 3 T/B rooftop (before removal)

■ Effects of introduction

One monitoring camera was used in the rubble removal work on the roof of Unit 3 T/B. It was able to get close to the target remote-controlled devices (SAM-installed BH, suction device). High-resolution video footage was taken from the optimum angle of view, such as local and bird's-eye views, of high quality, without delay. This improved remote operability and work efficiency. The camera could move across the irregular surface of the rubble without problems.

The charging base equipment, which could charge the camera in an unmanned and remote manner, reduced the radiation exposure related to the camera operation. We also placed shielding concrete around the charging base, to reduce the radiation emitted from the rooftop slab and to improve the maintainability of the equipment.


Mobile camera in operation


Mobile camera charging base

■ Main specifications

[Aerial work platform (4 m)] Dimensions 1,750 mm × 1,125 mm × 2,250 mm. Weight 870 kg.

[Charging base] Dimensions 3,385 mm × 1,536 mm. Weight 1,085 kg. Unmanned remote charging.

[Power source] On-board battery; DC 6V × 4, output 0.75 kW (running) /1.5 kW (elevation).

[Camera] Two units, for monitoring (upper mast) and running (front of vehicle body).

[Communication control] Wireless LAN (2.4 GHz), specified low power wireless.


Charging base floor shielding with concrete

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Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
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	No.	02-04
				7	Other		

Title	Dose reduction at a temporary storage site for high-dose containers, using shielding walls and simulation of shielding performance
Work location	Unit 3 turbine building sea-side yard
Overview	To reduce the air dose rate, shielding walls were installed at a temporary storage site for high-dose containers, which contained rubble removed from the roof of Unit 3 T/B. A simulation of shielding performance was confirmed at the planning stage.

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

Good Practice Description

■ Outline description

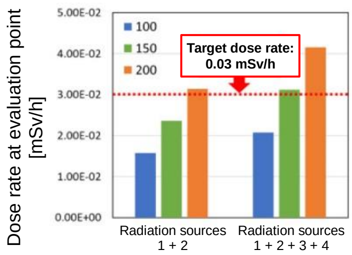
When a container containing high-dose rubble, which was removed from the rooftop of Unit 3 turbine building, was temporarily placed at the sea-side yard of that building, the air dose rate at the boundary of the work area had to be less than 0.1 mSv/h. Since the measured background air dose rate was about 0.07 mSv/h, we set the target dose rate due to contaminated rubble at 0.03 mSv/h or less. At the time of planning, the shielding effect was confirmed by a shielding simulation.

Shielding at Unit 3 T/B sea-side yard temporary container storage site

■ Effects of introduction

Two shielding walls were installed, using a box culvert. The dose rate was then simulated for two cases involving two radiation source containers and four radiation source containers, and for three cases measuring the container surface dose rates.

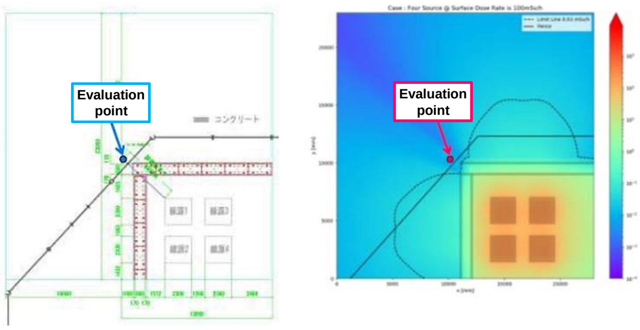
The measured dose rates were all below the target dose rates: below 100 mSv/h and 150 mSv/h for the case involving two radiation source containers, and below 100 mSv/h for the case involving four radiation source containers. This result was used as a guideline for the container surface dose rates when placing containers, and was used in work management. A simulation that can obtain evaluation results for ensuring safety in a short time by a simple calculation is effective for work planning.



Simulation results on air dose rate

Code		QAD-CGGP2R (3D)		
Radiation source (Debris)	Nucleus	Cs-137 : 85%, Cs-134 : 15%		
	Surface dose rate [mSv/h]	100	150	200
	Cs-137 radioactivity [Bq]	3.350×10^{12}	5.020×10^{12}	6.690×10^{12}
	Cs-134 radioactivity [Bq]	5.910×10^{11}	8.860×10^{11}	1.180×10^{12}
	Material	Concrete		
	Density [t/m3]	1.0		
	Number of radiation sources	2, 4		
Shield	Material	Concrete		
	Density [t/m^3]	2.1		
	Thickness [mm]	340 (170×2)		
System		Right figure		

Conditions for calculation



Shielding performance evaluation system and the resulting dose rate map

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Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	TB	4	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	No.	02-05
				7	Other		

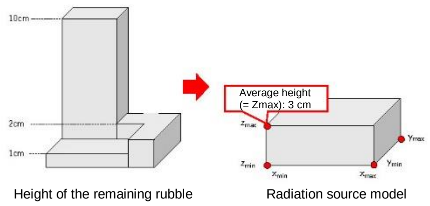
Title	Simulation of the air dose rate at a work site after removal of high-dose rubble
Work location	Unit 3 turbine building rooftop
Overview	On the rooftop of Unit 3 T/B, waterproofing work will be performed after rubble removal. The air dose rates at the waterproofing work locations were calculated by simulation.

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

Good Practice Description

■ Outline description

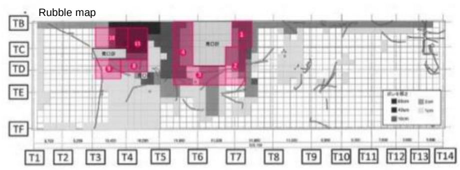
On the rooftop of Unit 3 T/B, waterproofing work will be performed after rubble removal. Before performing waterproofing works, it is necessary to know the air dose rates at work sites. Considering the possibility of there being contaminated rubble around the opening, we obtained the air dose rate at the work site by simulation.



Modeling of the radiation source by averaging the height of the remaining rubble

■ Details of simulation

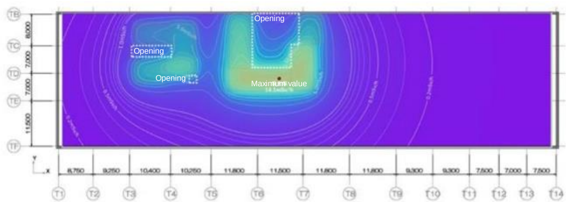
The point kernel code QAD-CGGP2R was used for the simulation. We divided the rooftop area into 2 m × 2 m grids and set the areas around the opening as a remaining rubble area. The height of the rubble was averaged for the purpose of modeling the radiation sources. The radioactivity of the remaining rubble was found by standardizing air dose rates of various areas, so that the modeled radiation sources, which were derived from the area and average height of each area.For simplification, the simulation did not consider the effects of adjacent areas. The average air dose rate for each area was calculated by superimposing the past air dose rate map and the grids and areas and pro-rating the dose rates with the area ratio.



Radiation source model for areas with remaining rubble (colored areas)

■ Effects of introduction

The waterproofing work was performed based on the calculation results. After the rubble removal, the actual air dose rates were reduced to one-quarter of those obtained by the simulation. A simulation that can ensure safety by obtaining evaluation results in a short time by a simple calculation is effective for work planning.



Simulation results on air dose rate

Edited by Taisei Corporation

<table>
<tr><th colspan="3">Location</th><th colspan="3">Category</th><th colspan="2" rowspan="6">Good Practices in Radiation Exposure Dose Reduction Measures</th></tr>
<tr><td>Inside reactor building</td><td>RB</td><td rowspan="7">RB</td><td rowspan="7">5</td><td>1</td><td>Time</td></tr>
<tr><td>Inside turbine building</td><td>TB</td><td>2</td><td>Distance</td></tr>
<tr><td>R ZONE</td><td>R</td><td>3</td><td>Shielding</td></tr>
<tr><td>Y ZONE</td><td>Y</td><td>4</td><td>Removing radiation source</td></tr>
<tr><td>G ZONE</td><td>G</td><td>5</td><td>Remote-control, robot operation</td></tr>
<tr><td rowspan="2">Other
( )</td><td rowspan="2">Z</td><td>6</td><td>Preventing spread of contamination</td><td rowspan="2">No.</td><td rowspan="2">02-06</td></tr>
<tr><td>7</td><td>Other</td></tr>
<tr><td colspan="2">Title</td><td colspan="6">Remote operation of rubble fall prevention and mitigation works at Unit 1 operating floor</td></tr>
<tr><td colspan="2">Work location</td><td colspan="6">Unit 1 reactor building operating floor (the top floor)</td></tr>
<tr><td colspan="2">Overview</td><td colspan="6">To reduce radiation exposure,rubble fall prevention and mitigation measures were remotely performed (or done).</td></tr>
<tr><td colspan="2" rowspan="3">Assessment (Qualitative / quantitative)</td><td colspan="2" rowspan="3">Effects</td><td colspan="2"></td><td>Before Implementation</td><td>After Implementation</td></tr>
<tr><td colspan="2">Radiation exposure dose (mSv)</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Person time (person-days)</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Good Practice Description</td><td colspan="6"></td></tr>
</table>

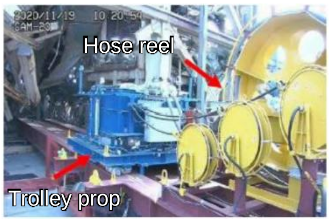
- A damaged FHM overhead crane was located on the SFP on the Unit 1 operating floor. Rubble, including broken steel roof frames, had accumulated on the SFP. In such a situation, removal of rubble may cause dust scattering or adverse effects on stored fuel, because the damaged crane may fall and reach the SFP. In addition, since the Unit 1 operating floor had a high dose (40-80 mSv/h) and was located 30 m above the ground, it was not possible for workers to work on site. So, we dealt with the rubble fall prevention and mitigation by remote operation.
- The main construction works for the measure were protecting the surface of the SFP, installing a prop beam for the FHM, and installing a prop for the overhead crane. To prepare an environment for conducting these construction works, the X braces on the west, south, and east walls were cut and removed. To reduce radiation exposure,the removal of floor rubble and all other works were remotely done.

The collapsed roof of Unit 1 operating floor

Overview of the rubble fall prevention and mitigation work

SFP protective bag installed

Prop beam for FHM inserted



Prop trolley for overhead crane

Details of rubble fall prevention and mitigation works

Edited by Hitachi-GE Nuclear Energy, Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	Z	17	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

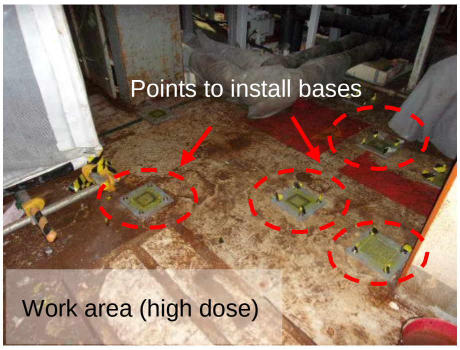
No.	02-07

Title	1F Units 2 to 4: Installation of safety aisles and development of the working environments
Work location	Unit 2 Rw/B, Unit 3 Rw/B and T/B, and Unit 4 R/B
Overview	Safety aisles are located in high dose rate areas. We used a low dose rate area to reduce radiation exposure.

Assessment (Qualitative / quantitative) — Effects

	Before Implementation	After Implementation
Dose rate (mSv/h)	0.5	0.01
Person time (person-days)	–	–

Good Practice Description	Since the locations of safety aisles had high dose, alternative aisles were produced in-house, at a production site in a low dose area. Only those works that required on-site adjustment, such as base setting, were performed on site. As a result, the exposure was reduced by shortening the working time in the high dose areas.



Workload in high dose rate area was reduced

Aisles were produced at a low dose rate area

Work area	Dose rate (mSv/h)
Unit 2 Rw/B	-0.50
Unit 3 Rw/B	-0.50
Unit 3 T/B	-0.16
Unit 4 T/B	-0.05
Production site	<0.01

Edited by Hitachi Plant Construction, Ltd.

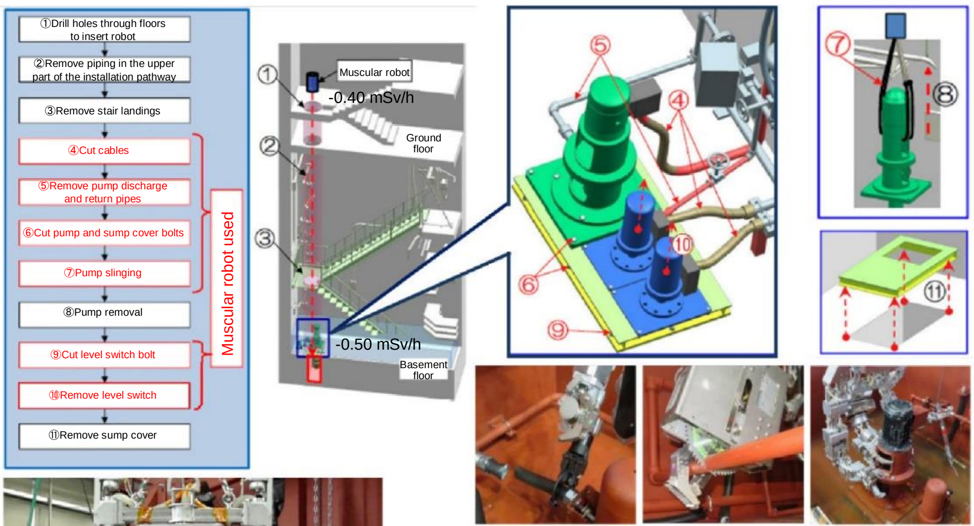
Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	TB	5	1	Time		
Inside turbine building	TB			2	Distance		
R ZONE	R			3	Shielding		
Y ZONE	Y			4	Removing radiation source		
G ZONE	G			5	Remote-control, robot operation		
Other ( )	Z			6	Preventing spread of contamination	No.	02-08-01
				7	Other		

Title	Units 1 to 4: Radiation exposure dose reduction in the installation of retained-water discharging equipment
Work location	Unit 3 turbine building service area
Overview	Since it was difficult to work on site at the basement floor, due to the high dose rate and the presence of retained water, we chose to operate a muscular robot remotely.

Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Dose rate (mSv/h)	-50	-0.4
		Person time (person-days)	—	—

Good Practice Description	Obstacles in the basement floor, which had a high dose rate, were removed using a muscular robot.

Obstacles to be removed and tasks for the muscular robot



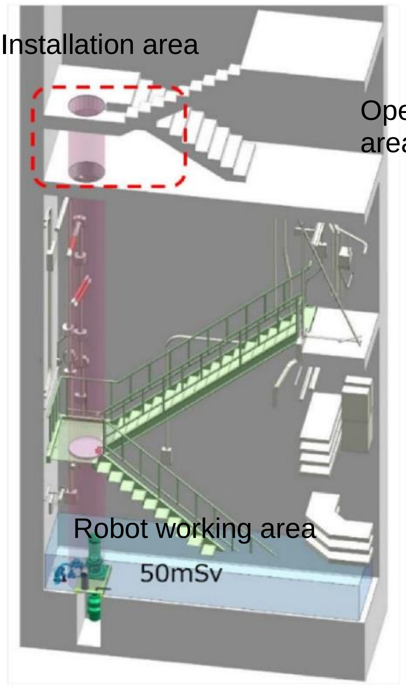
Cut cable Cut pipe Slinging

Entire view of the muscular robot

Edited by Hitachi-GE Nuclear Energy, Ltd.

Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	TB	3 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	No.	02-08-02
				7	Other		

Title	Units 1 to 4: Radiation exposure dose reduction in the installation of retained-water discharging equipment		
Work location	Unit 3 turbine building service area		
Overview	Since it was difficult to work on site at the basement floor, due to the high dose and the presence of retained water, a muscular robot was operated remotely and the work site was shielded.		
Assessment (Qualitative / quantitative)	Effects	Before Implementation	After Implementation
	Dose rate (mSv/h)	0.40	0.02
	Person time (person-days)	—	—
Good Practice Description	When installing the muscular robot from the opening on the ground floor, shielding was installed to reduce radiation from the basement floor.		



The robot was installed from the opening on the ground floor.

Shielding

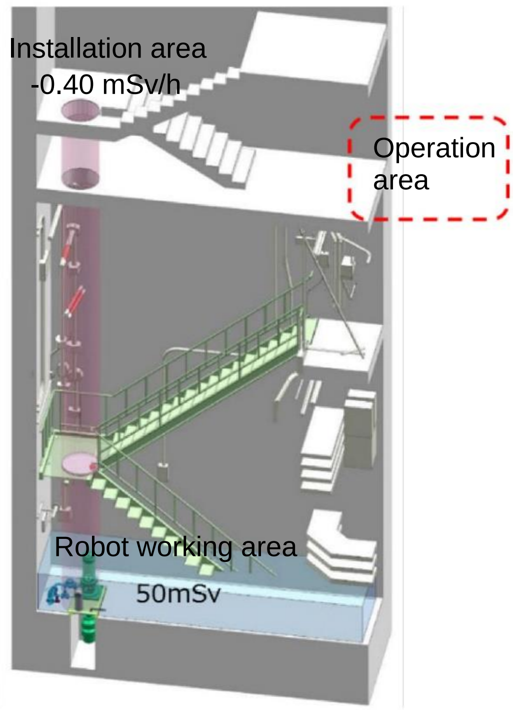
×1 ~0.40mSv/h
×2 ~0.02mSv/h

Shielding was installed to reduce radiation from the basement floor.

The installation could be operated in a low dose rate area.

Edited by Hitachi-GE Nuclear Energy, Ltd.

<table>
<tr><th colspan="3">Location</th><th colspan="3">Category</th><th colspan="2" rowspan="6">Good Practices in Radiation Exposure Dose Reduction Measures</th></tr>
<tr><td>Inside reactor building</td><td>RB</td><td rowspan="7">TB</td><td rowspan="7">2
5</td><td>1</td><td>Time</td></tr>
<tr><td>Inside turbine building</td><td>TB</td><td>2</td><td>Distance</td></tr>
<tr><td>R ZONE</td><td>R</td><td>3</td><td>Shielding</td></tr>
<tr><td>Y ZONE</td><td>Y</td><td>4</td><td>Removing radiation source</td></tr>
<tr><td>G ZONE</td><td>G</td><td>5</td><td>Remote-control, robot operation</td></tr>
<tr><td rowspan="2">Other
( )</td><td rowspan="2">Z</td><td>6</td><td>Preventing spread of contamination</td><td rowspan="2">No.</td><td rowspan="2">02-08-03</td></tr>
<tr><td>7</td><td>Other</td></tr>
<tr><td colspan="2">Title</td><td colspan="6">Units 1 to 4: Radiation exposure dose reduction in the installation of retained-water discharging equipment</td></tr>
<tr><td colspan="2">Work location</td><td colspan="6">Unit 3 turbine building service area</td></tr>
<tr><td colspan="2">Overview</td><td colspan="6">Since it was difficult to work on site at the basement floor, due to the high dose and the retained water, a remote operated muscular robot was employed. A low dose area was chosen for the operation.</td></tr>
<tr><td colspan="2" rowspan="3">Assessment
(Qualitative /
quantitative)</td><td colspan="2" rowspan="3">Effects</td><td colspan="2"></td><td>Before Implementation</td><td>After Implementation</td></tr>
<tr><td colspan="2">Dose rate (mSv/h)</td><td>0.40</td><td>0.013</td></tr>
<tr><td colspan="2">Person time (person-days)</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Good Practice Description</td><td colspan="6">A muscular robot operation area was set up in a low dose area.</td></tr>
</table>



The robot was operated from the operation area in a low dose rate area.

Operation area: -0.013 mSv/h

Radiation exposure doses of operators were reduced

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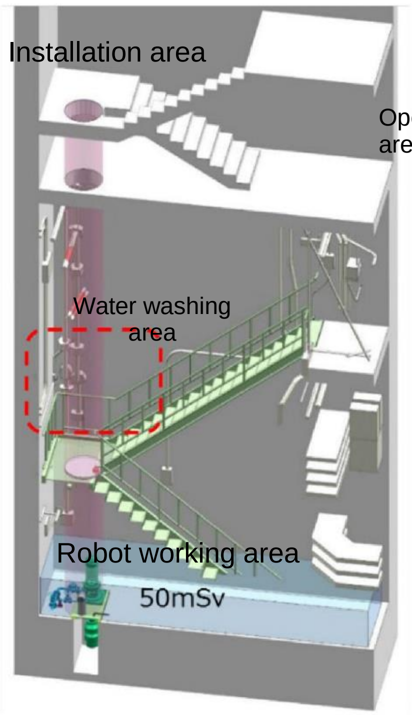
Location			Category				
Inside reactor building	RB	TB	3 4 5	1	Time	Good Practices in Radiation Exposure Dose Reduction Measures	
Inside turbine building	TB			2	Distance		
R ZONE	R			3	Shielding		
Y ZONE	Y			4	Removing radiation source		
G ZONE	G			5	Remote-control, robot operation		
Other ( )	Z			6	Preventing spread of contamination	No.	02-08-04
				7	Other		

Title	Units 1 to 4: Radiation exposure dose reduction in the installation of retained-water discharging equipment		
Work location	Unit 3 turbine building service area		
Overview	Since it was difficult to work on site at the basement floor, due to the high dose and the retained water, a remote operated muscular robot was employed. When taking the robot from contaminated water, different measures were taken to reduce the exposure doses.		

Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Dose rate (mSv/h)	12	0.35
		Person time (person-days)	—	—

Good Practice Description	Muscular robots and other items became contaminated due to their use on the basement floor. To prevent the accumulation of contamination (i.e., increase in dose rates or contamination level) on the equipment, we cleaned them after every use. To reduce the exposure dose of the worker performing the cleaning, the cleaning area was shielded and a long nozzle was used.



When taking the robot from the basement floor, it was cleaned with high-pressure water.

The accumulation of contamination and increased dose rates were prevented.

×1 12mSv/h
×2 1.2mSv/h
×3 0.35mSv/h

To reduce radiation exposure to workers while cleaning, shielding was installed to reduce radiation from the basement floor.

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Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	Z	5 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	No.	02-09
				7	Other		

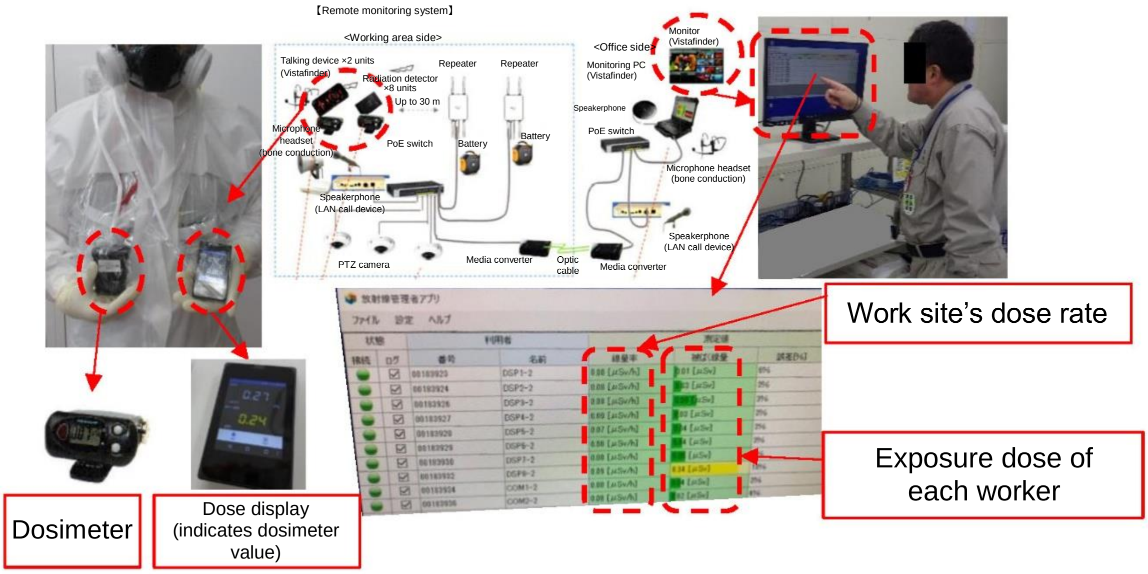
Title	Remote monitoring system for individual exposure dose			
Work location	High dose rate areas in 1F building			
Overview	For those working in high dose rate areas, a remote monitoring system is used, to check their exposure dose rates in real time.			
Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	–	–
		Person time (person-days)	–	–
Good Practice Description				

■ Outline description

The system that remotely monitors individual exposure dose (called the “remote monitoring system”) requires workers to carry a dosimeter and a dose display during their work, to collect exposure data. These devices transmit the measured values to the monitor in the monitoring room in real time. In addition, by using cameras installed at work sites and voice communication devices carried by the workers, the workers could be given instructions remotely while images of the work site were checked in the monitoring room.

■ Effects of introduction

- Since the system allowed remote monitoring of the exposure dose of each worker and the dose rates at work sites, it was possible to check exposure doses and measure dose rates without entering high dose rate working areas. In this way, the exposure of radiation control officers was successfully reduced.
- Since the exposure dose and the dose rate at the current work site were displayed on the dose display carried by the worker, the worker could confirm the exposure dose and the current dose rate in real time, while working.
- Since both supervisors and workers knew the exposure dose and the dose rates at the work sites, unintentional accumulation of exposure or entries into high dose rate areas could be prevented.



Location			Category			Good Practices in Radiation Exposure Dose Reduction Measures	
Inside reactor building	RB	Z	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	No.	02-10
				7	Other		

Title	ALARA activities			
Work location	1F building			
Overview	To reduce exposure dose, we performed the PDCA cycle over the exposure reduction processes, as the ALARA (As Low As Reasonably Achievable) activity.			
Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	–	–
		Person time (person-days)	–	–
Good Practice Description				

■ Outline description

The ALARA activity refers to a set of processes to perform the following PDCA steps for construction works that involve a total planned dose exceeding 0.5 person-Sv or an individual dose exceeding 15 mSv/year. The purpose is to improve the accuracy of work planning and reduce exposure dose.

[P] Planning of radiation exposure dose reduction measures

- Hold an ALARA meeting to deliberate on the appropriateness of the radiation exposure dose reduction measures to be taken.
- Review the radiation control plan to confirm the appropriateness of the plan (i.e., planned exposure doses, etc.).

[D] Do (implement) the planned measures

- Implement the planned radiation exposure dose reduction measures.

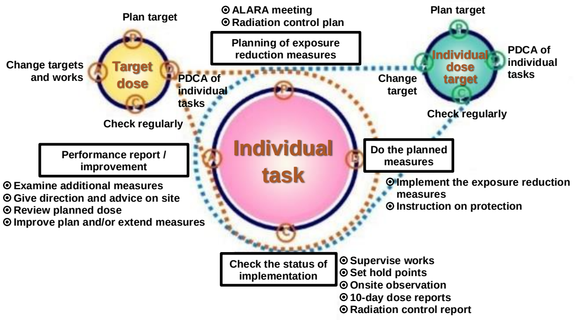
[C] Check the status of implementation

- Observe the site. Confirm the effect of the radiation exposure dose reduction measures taken.
- Check if any additional exposure reduction measure is required.
- Make a 10-day dose report* and compare the discrepancy between planned and actual doses every 10 days.
- For long-term construction, hold an interim debriefing session of the ALARA meeting to confirm the performance of the radiation exposure dose reduction measures taken.

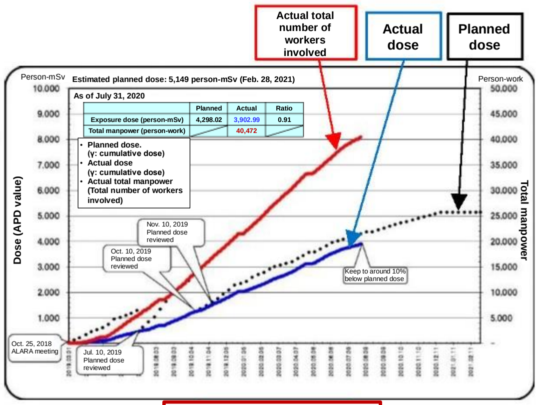
[A] Performance report / improvement

- Share good practices and matters to be improved, taken from on-site observation. Use them in actual works.
- If any significant discrepancy is identified in the 10-day dose report,* investigate the cause(s), implement necessary measures, and review the planned dose.
- Share the knowledge obtained from the ALARA meetings (including the interim debriefing session) and use it in actual works.

* The 10-day dose report is a graph of the cumulative planned and cumulative actual doses every 10 days.



Processes of exposure reduction



10-day dose report

Edited by Tokyo Electric Power Company Holdings, Inc.

<table>
<tr><th colspan="3">Location</th><th colspan="3">Category</th><th colspan="2" rowspan="7">Good Practices in Radiation Exposure Dose Reduction Measures</th></tr>
<tr><td>Inside reactor building</td><td>RB</td><td rowspan="6">RB
R</td><td rowspan="7">2
5</td><td>1</td><td>Time</td></tr>
<tr><td>Inside turbine building</td><td>TB</td><td>2</td><td>Distance</td></tr>
<tr><td>R ZONE</td><td>R</td><td>3</td><td>Shielding</td></tr>
<tr><td>Y ZONE</td><td>Y</td><td>4</td><td>Removing radiation source</td></tr>
<tr><td>G ZONE</td><td>G</td><td>5</td><td>Remote-control, robot operation</td></tr>
<tr><td rowspan="2">Other
( )</td><td rowspan="2">Z</td><td>6</td><td>Preventing spread of contamination</td></tr>
<tr><td></td><td>7</td><td>Other</td><td>No.</td><td>02-11</td></tr>
<tr><td colspan="3">Title</td><td colspan="5">Securing distance from high-dose 6 m^3 containers, and further Improvement (“Kaizen”) of the engineering method</td></tr>
<tr><td colspan="3">Work location</td><td colspan="5">Unit 2 R/B pre-clean room area above gantry</td></tr>
<tr><td colspan="3">Overview</td><td colspan="5">To reduce exposure doses of radiation control officers, a shielding box was installed to confirm the degree of contamination of a 6 m^3 container with a high dose rate, using a smear-taking jig.</td></tr>
<tr><td colspan="3" rowspan="3">Assessment (Qualitative / quantitative)</td><td rowspan="3">Effects</td><td colspan="2"></td><td>Before Implementation</td><td>After Implementation</td></tr>
<tr><td colspan="2">Radiation exposure dose (mSv)</td><td>—</td><td>—</td></tr>
<tr><td colspan="2">Person time (person-days)</td><td>—</td><td>—</td></tr>
<tr><td colspan="3">Good Practice Description</td><td colspan="5"></td></tr>
</table>

Before implementation: Before moving a 6 m^3 container with a high dose, it was necessary to confirm the degree of contamination of the container. The confirmation work involved a risk of exposure.

Details of measures: The radiation control officer used an extended smear-taking stick from the shielded box to confirm the contamination of the container.

Radiation control officers’ waiting area

Shielded box

Smear stick (extendable)

Dose equivalent rate inside the box: 4.0 mSv/h ⇒ 2.0 mSv/h

Steel plate＋lead: 22 mm + 9 mm
Shielding effectiveness: approx. 54%

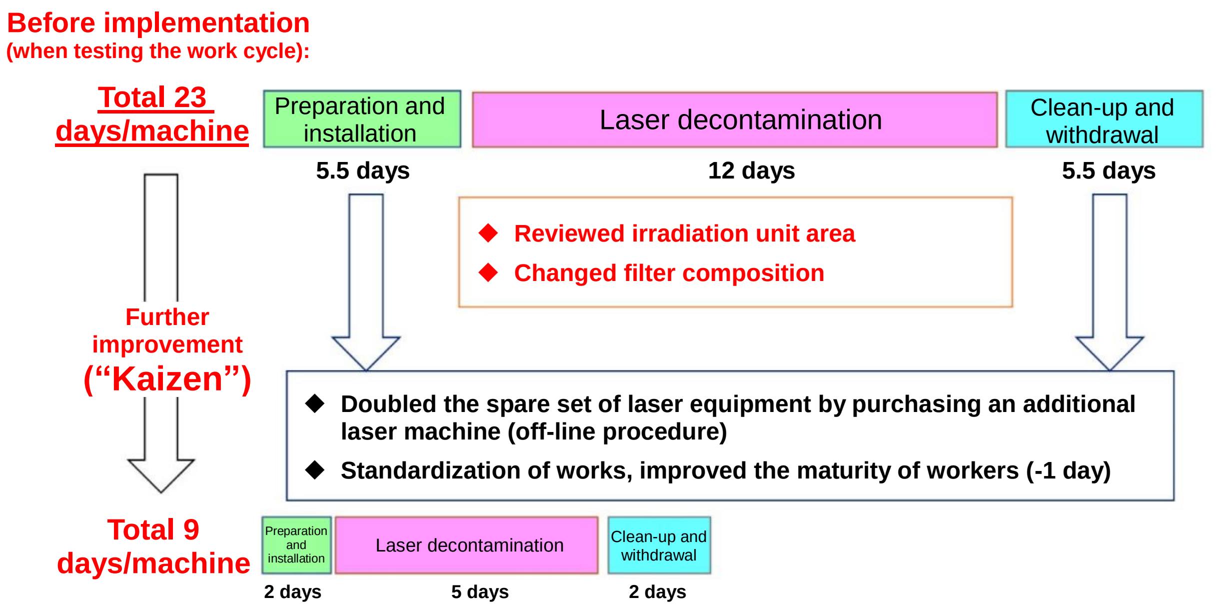
Extendable to 6 m

Edited by Tokyo Power Technology Ltd.

Location			Category				
Inside reactor building	RB	Y	1	1	Time	Good Practices in Radiation Exposure Dose Reduction Measures	
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	No.	02-12
				7	Other		

Title	Radiation exposure dose reduction by further improving ("Kaizen") laser decontamination techniques			
Work location	E Area			
Overview	The laser decontamination technology reduction of radiation exposure by further improving ("kaizen") the laser decontamination techniques that we reported last year.			
Assessment (Qualitative / quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	γ 1.036 person-mSv β13.805 person-mSv	γ 0.66 person-mSv β5.3 person-mSv
		Person time (person-days)	138 person-days	54 person-days
Good Practice Description				

During practical use of laser decontamination technology, further improving ("kaizen") was implemented, and radiation exposure dose reduction measures with improved efficiency of the work cycle.



Edited by Taisei Corporation

Good Practices

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

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