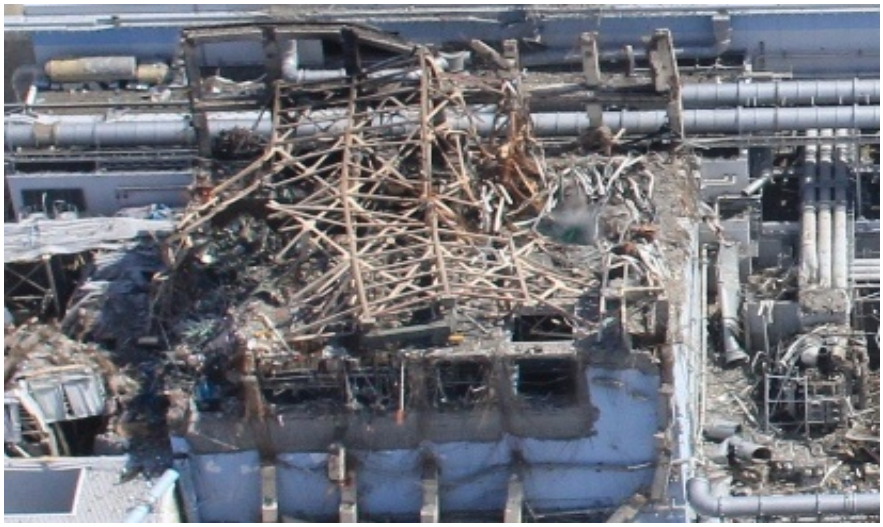
Commissioned by the Ministry of Health, Labour and Welfare in FY2016
Project to Enhance the International Transmission of Radioactivity-Related Information on the Workers at TEPCO Holdings' Fukushima Daiichi Nuclear Power Plant

Good Practices in Radiation Exposure Dose Reduction Measures



1F-Unit 3 Reactor Building 5F State Immediately After the Accident

1F-Unit 3 Reactor Building 5F Conceptual Illustration of the Fuel Removal Framework as

Source: Kajima Corporation

Edited: Japan Environment Research Co.,Ltd.

Principles for Radiation Exposure Protection

(1) Reducing external exposure

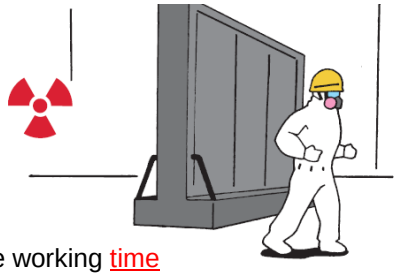
To reduce **external exposure,** it is important to understand the following four principles of radiation exposure protection

Principle 1 Remove radioactive materials

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

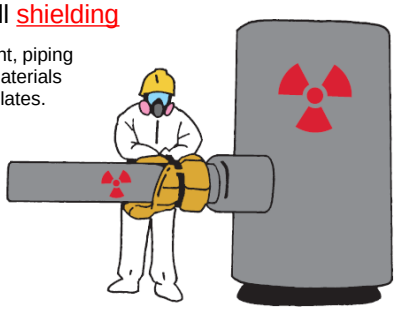
Principle 2 Maintain sufficient distance from radiation

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

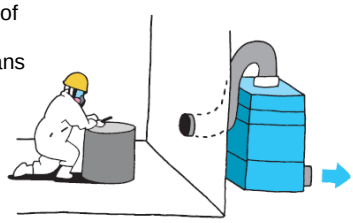
Measures also need to be put in place to prevent radioactive materials from being blown around in the air, as well as to contain (and limit) any contamination and stop it spreading (dispersing).

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

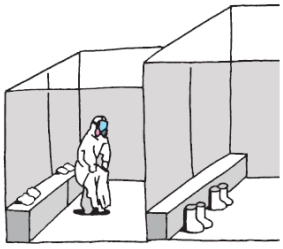


Principle 3 Move to safety

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 Zoning Area Control

(1) 1F Site Zoning Area Status

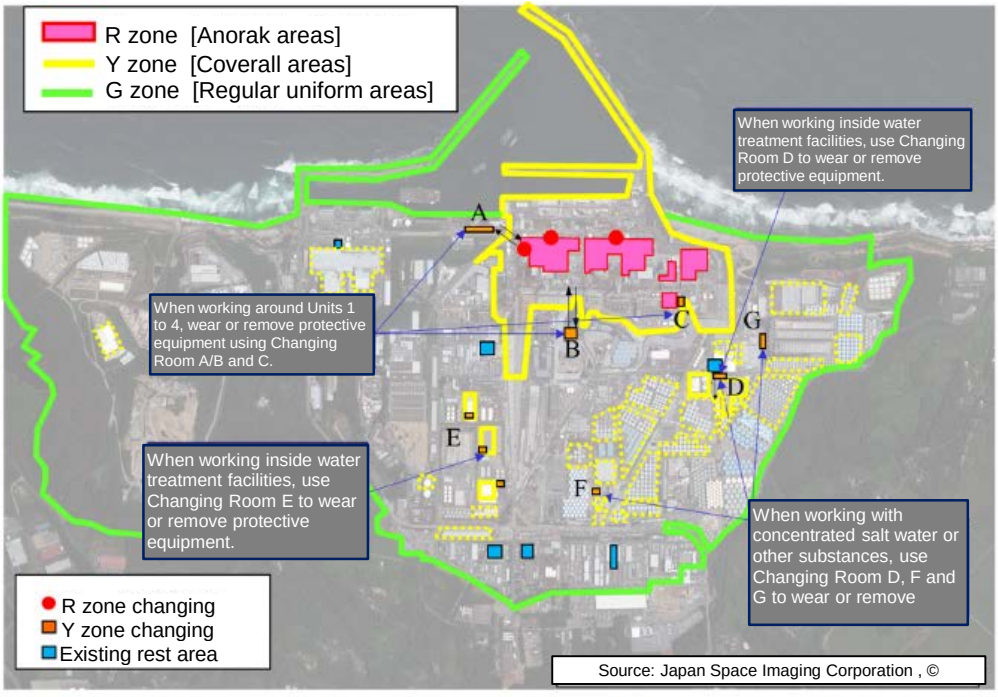
Condition			Zone		Protective Equipment
Control Zone	Areas Requiring Full-face/Half-face Mask	Heavily Contaminated Area	Red zone (Anorak areas) ・Inside unit 1 to 3 reactor buildings ・Areas with stored water around unit 1 to 4 reactor buildings		・Full-face mask ・2 layer coverall or anorak ・Work boots (for R zone) ・Helmet (for R zone) ・Cotton gloves + rubber gloves
		β-ray Area (areas with potential exposure to β-rays)	Yellow zone (Coverall areas)	・Inside buildings that include water treatment facilities (such as desalinination units, multi-nuclide removal facilities)*1 ・Work in areas around tanks that contain concentrated salt water, strontium-treated water*2, 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
		Areas other than above		・Around unit 1 to 4 buildings (4 m/10 m circle) ・Specified as required to suit work environment (such as inside unit 5, 6 building, 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
	Area Not Requiring Full-face Mask		Green zone (Regular uniform areas) Areas excluding the above		・DS mask ・Site clothing, regular work clothing*3 ・Work boots (for G zone) ・Helmet (for G zone) ・Cotton gloves + rubber gloves or work gloves
	Control zones with no Risk of Contamination		・Inside important anti-seismic buildings and inside rest areas		

*1: Excludes observations and other operations that are not considered work.

*2: Excluding work that does not involve the handling of concentrated salt water, patrolling, field surveys in the work planning phase, observation visits, etc.

*3: Certain light work (such as patrolling, monitoring and transportation of items brought in from outside the premises).

(2) 1F site area map



* When working with highly concentrated dust (such as demolishing buildings) in the G zone, or working with concentrated salt water in areas outside of the above map, those areas will be temporarily specified as the Y zone.
* The Y zone shown in yellow dotted lines is for when working with concentrated salt water or work related to contamination such as tank transfer lines, and requires G zone equipment during patrols or field surveys in the work planning phase.

Contents List of Good Practice in Radiation Exposure Dose Reduction Measures

No.	Location	Category	Title	Radiation exposure dose equivalent (mSv)			Time (person-days)		Notes
				Before Implementation	After Implementation	Reduction Amount	Before Implementation	After Implementation	
28-01	RB	1	Reducing exposure dose by changing cable storage location	--	--	--	--	--	
28-02-1	RB	4	Decontaminating with remote operation	--	--	--	--	--	
28-02-2	RB	5	Demolishing trusses and removing their debris with remote operation	--	--	--	--	--	
28-03-1	RB	5	Removing small rubble piecies with rubble suction system	3,021	1,278	1,743	8,036	4,088	
28-03-2	RB	5	Using a large rubble (obstructing steel frames) removal device	3,021	1,278	1,743	8,036	4,088	
28-04	RB	5	Surveying the TIP room using a small robot (investigating the state of the inside of the room /measuring radiation exposure dose rate)	--	--	--	--	--	
28-05	RB	5	Surveying MSIV room by inserting long pole into the room (Investigating state of the inside room/measuring dose rate)	--	--	--	--	--	
28-06	RB	6	Preventing dust generation when removing rubble (by spraying mist)	3,021	1,278	1,743	8,036	4,088	
28-07	RB	7	Efficiency improvement of handling suction hose and other assisting operations (improving work method)hose assisting operations.	--	--	--	--	--	
28-08	TB	2	Ensuring distance by using remote-controlled devices	10,079	2,984	--	--	--	
28-09	TB	4	Flushing heater drain (HD) piping (removing radiation source)	10,079	2,984	--	--	--	
28-10	TB	7	Changing access routes to low-radiation exposure dose rate areas	10,079	2,984	--	--	--	
28-11	R	1	Installing prefabricated shelters off-site to simplify site work (changing work location)	--	--	1,069	--	220	
28-12	R	3	Installing shielded booth	--	--	66	--	--	
28-13	R	3	Utilizing shielded boxes from other work (improving work method)	--	--	--	--	--	
28-14	R	7	Clearly display radiation exposure dose at work areas	--	--	--	--	--	
28-15	R	7	Reducing site work by using existing structures (improving work method)	--	--	553	--	--	
28-16	Y	1	Changing excavator bucket installation orientation	--	--	--	--	--	
28-17	Y	3	Shielding surveying machinery control room	--	--	--	--	--	70 → 25 μSv/h
28-18	Y	6	Sheet covering during removal and storage of contaminated soil	--	--	--	--	--	
28-19	G	5	Topographic surveying of inclined ground using drones	13.5	0.5	13	270	24	
28-20	G	7	Providing rest facilities	--	--	--	--	--	
28-21	G	7	Mechanization of mowing work	12	2.5	9.5	240	62	
28-22	G	7	Reducing the amount of protective equipment worn with more detailed site zones	--	--	--	--	--	
28-23	Z	1	Conducting mockup training	--	--	--	--	--	
28-24	Z	2	Changing work location (assembly work at low dose rate areas)	--	--	--	--	--	
28-25	Z	3	Shielding and partitioning transportation routes with a high radiation exposure dose rate	--	--	44.5	--	--	10 → 5 mSv/h
28-26	Z	5	Monitoring using remote-controlled cameras/installing area monitors	--	--	--	--	--	
28-27	Z	6	Preventing contamination from being brought in	--	--	--	--	--	
28-28	Z	7	Preventing internal exposure by wearing two layers of masks	--	--	--	--	--	

Good Practice 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.	28-01

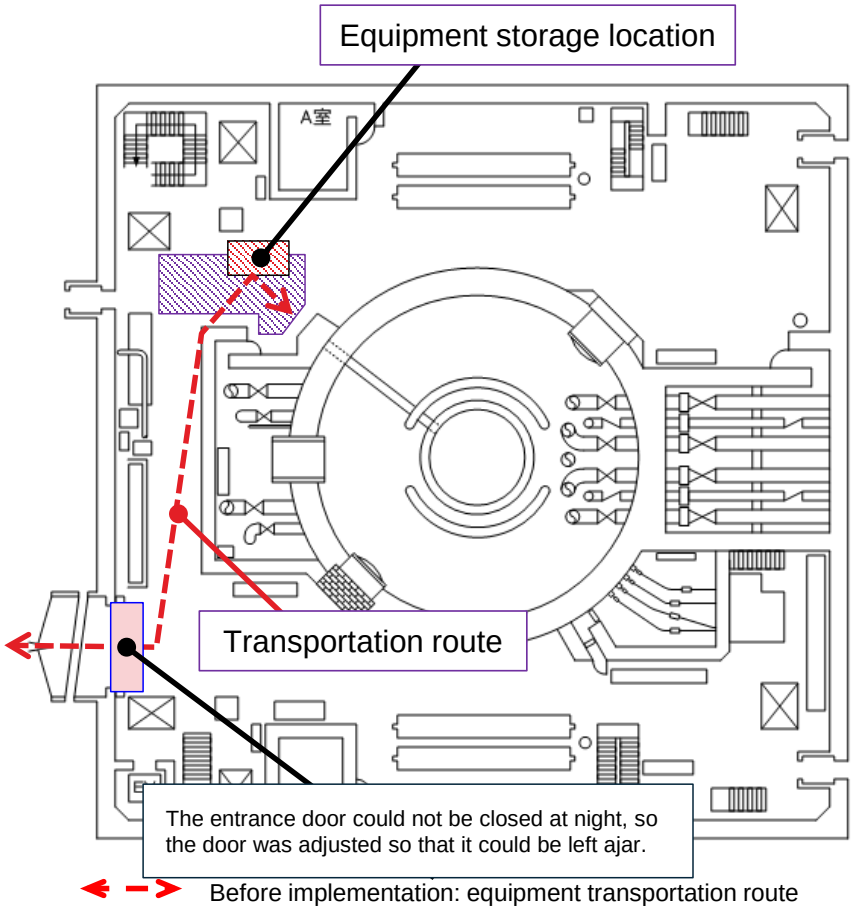
Title	Reducing exposure dose by changing cable storage location
Work location	Inside Unit 3 reactor building
Overview	Changed from transporting cables for decontamination equipment every day, to storing them inside the building

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

Good Practice Description

Before Implementation: Decontamination equipment was carried in and out of buildings everyday, creating the need for assisting operations for cables and other accessories, and increasing the exposure dose.

Implementation Details: Operation was changed so that decontamination equipment could be stored in the work area inside the building, which reduced the amount of assisting operations when carrying the cables in and out.



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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	RB	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
				7	Other

No.	28-02-1

Title	Decontaminating by remote operation
Work location	Unit 3 reactor building, 5F (operation floor)
Overview	Decontamination (removal of radiation sources) was conducted due to the contamination status on the operation floor

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

Good practice description

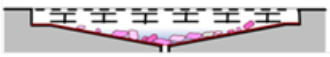
*Scabbler: process that involves mechanically chipping away the surface of concrete

Before Implementation

The air dose rates above the operation floor were high and the floor was extremely contaminated, with conditions such that decontamination by workers would result in a high radiation exposure dose.

Implementation Details

Decontamination methods were determined based on the contamination status on the floor, and special equipment was selected for each area listed below and used to remove the radiation sources.

	(1) t ≥ 600 slab	(2) t = 300 slab	(3) Cask washing area
Assumed state			
Contamination type	Penetration (epoxy assumed to be damaged)	Penetration	Surface layer
Material	RC + epoxy	RC + epoxy	Stainless steel
Surface area	440 m^2	260 m^2	70 m^2
Decontamination method	Scabbler	Water jet	Chemical (foam-based) decontamination
Reason for selection	・Highest chipping capability ・Highest work speed	・Chipping is possible for the floor surface with cracks and some irregulations	・Effectiveness was confirmed particularly for metric material in a decontaminatio test using actual wastes
Expected effects	・According to the literature, the radioactivity level at a depth of 5 mm from the surface is about 1/100 of the level at the surface.	・According to the literature, the radioactivity level at a depth of 5 mm from the surface is about 1/100 of the level at the surface (The radioactivity level reduction rate for cracked parts is unknown.)	・The radioactivity level was reduced to 1/10 or less by the decontamination work
Typical external appearance of the equipment			

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Good Practice in Radiation Exposure Dose Reduction Measures

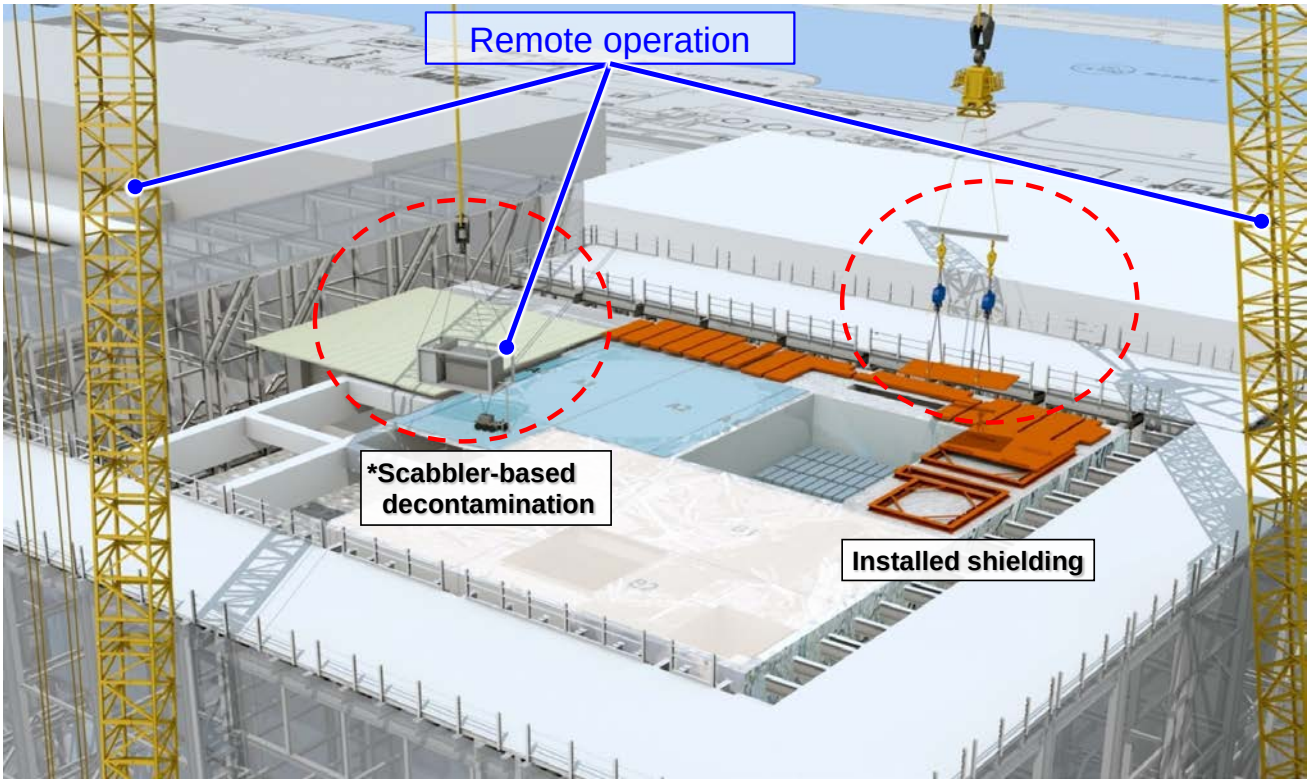
Location			Category		
Inside reactor building	RB	RB	5	1	Time
Inside turbine building	TB			2	Distance
R ZONE	R			3	Shielding
Y ZONE	Y			4	Removing radiation source
G ZONE	G			5	Remote-control, robot operation
Other ( )	Z			6	Preventing spread of contamination
				7	Other

No.	28-02-2

Title	Demolishing trusses and removing their debris by remote operation
Work location	Unit 3 reactor building, 5F (operation floor)
Overview	Trusses were demolished and their debris was removed using cranes and heavy demolition equipment with remote operations

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

Good practice description	*Scabbler: process that involves mechanically chipping away the surface of concrete
Before Implementation	The air dose rates above the operation floor were high and the floor was extremely contaminated, with conditions such that demolishing trusses and removing their debris by workers would result in a high radiation exposure dose.
Implementation Details	Debris on the operation floor was demolished and removed with s large crawler crane and heavy demolition equipment deployed on a temporary lower platform. Both the crane and the heavy demolition equipment were remotely operated.



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Good Practice 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.	28-03-1

Title	Removing small rubble piecies with rubble suction system
Work location	Unit 1 reactor building, 5F (operation floor)
Overview	Suctioning and removing small rubble pieces with remote-controlled rubble suction system

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	*3021	*1278
	Person time (person-days)	8036	4088

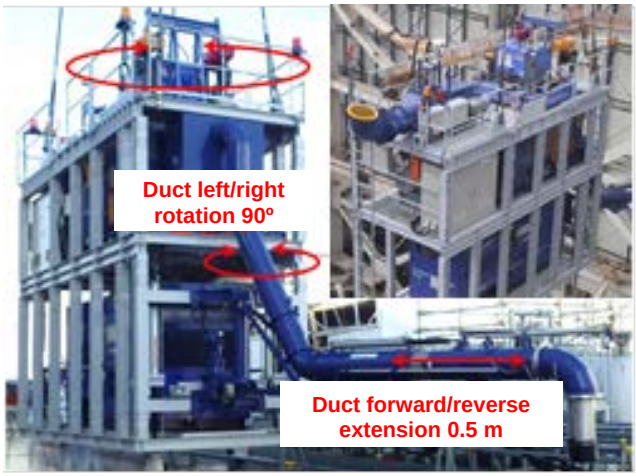
* Total values of 28-03-1, 28-03-2, and 28-06

Good practice desctiption	
Before Implementation	Rubble varied widely in size, and suctioning rubble with one size of rubble suction system was difficult.
Implementation Details	A remote-controlled rubble suction system for small rubble piecies was developed and utilized (same as for large rubble removal system)

(1) Suctioning small rubble pieces using remote-controlled rubble suction system

Due to the explosion inside the reactor building after the earthquake, there were countless pieces of small rubble such as concrete strewn across the existing operation floor. This interfered with the installation of mist spray equipment (nozzle unit steel frames), and needed to be removed.

Given the high elevation, high radiation exposure dose rate environment, equipment was developed that could suction small pieces of rubble via remote operation. The remote guidance system that was developed while installing the cover was used to suction small pieces of rubble.



▲ Rubble suction system

▲ Rubble suction in progress

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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 Practice in Radiation Exposure Dose Reduction Measures

No.	28-03-2

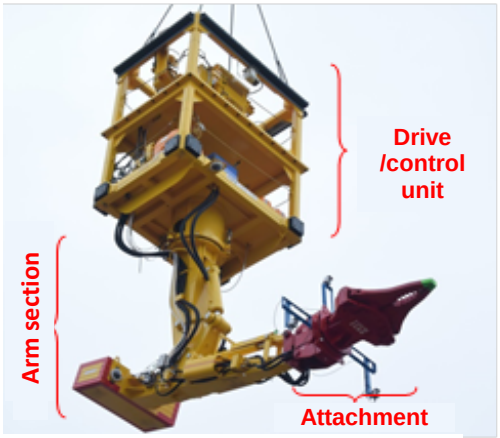
Title	Using a large rubble (obstructing steel frames) removal device
Work location	Unit 1 reactor building, 5F (operation floor)
Overview	Large rubble (obstructing steel frames) removal equipment was developed, and used via remote operation

Assessment (qualitative/quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	*3,021	*1,278
		Person time (person-days)	8,036	4,088

* Total values of 28-03-1, 28-03-2 and 28-06

Good Practice description	
Before Implementation	Rubble varied widely in size, and removing rubble with one size of rubble removal equipment was difficult.
Implementation Details	Remote-controlled rubble removal equipment for large rubble was developed and utilized.

(2) Removing large rubble piecies (obstructing steel frames) using remote-controlled rubble removal equipment
In addition to small rubble pieces across the existing operation floor steel frame, large rubble pieces such as bent steel frames and piping caused other objects to catch and interfere with operations.
Small rubble removal equipment with cutting and pinching functions was developed, and used to remove large rubble pieces via remote operations similarly to suction of small rubble pieces.



▲ **Equipment overview**
(used by hoisting with crane)
Weight: approx. 18 t
Drive unit: Hydraulic

Small cutter ▼

Good Practice 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.	28-04

Title	Surveying the TIP room using a small robot (investigating the state of the inside of the room /measuring radiation exposure dose rate)
Work location	Unit 1 reactor building, 1F, TIP room
Overview	The state inside the TIP room was unknown, so a small robot was used to survey the area

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

Good Practice Description

Before Implementation
There was a high possibility of a high radiation exposure dose rate inside the TIP room, so it was not possible for workers to enter the area, and its state remained unknown.

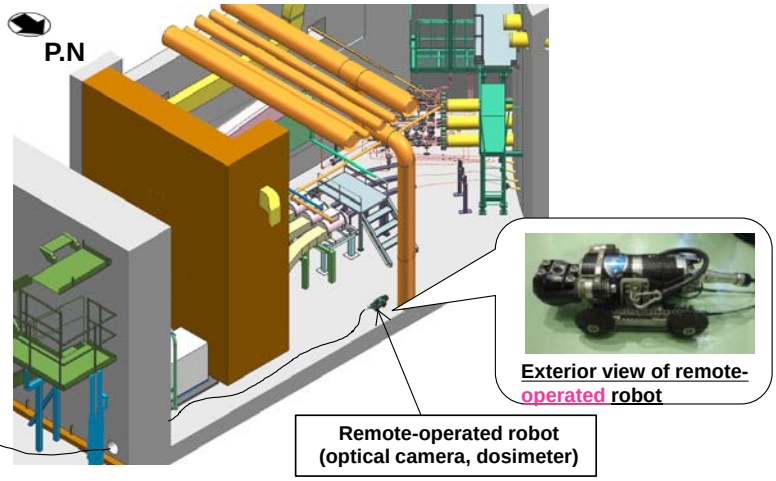
Implementation Details
A hole was drilled in a wall and a small robot moved inside to measure the environment radiation exposure dose rate and also survey the state inside the TIP room. Workers operated the robot remotely from a nearby area with a low radiation exposure dose rate, which prevented any unnecessary exposure.

The dose rate in the room atmosphere is unknown

A hole is drilled in a wall to gain access to the inside of the room

Survey using small remotely-operated robot
- **Workers operated the robot from an area with a low radiation exposure dose**
- **The robot is small enough to be able to enter the room through a small hole**

Robot operated remotely from low radiation exposure dose area



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Good Practice 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.	28-05

Title	Surveying MSIV room by inserting long pole into the room (investigating state of the inside room/measuring dose rate)
Work location	Unit 1 reactor building, 1F, MSIV room
Overview	The state inside the MSIV room was unknown, so a 3D laser scanner was used to survey the area

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

Good Practice Description

Before Implementation A high radiation exposure dose rate was expected inside the MSIV room, so it was not possible for workers to enter the area, and its state remained unknown.

Implementation Details A long pole was used to measure the radiation exposure dose rate and survey the state inside the MSIV room from a low radiation exposure dose rate area.

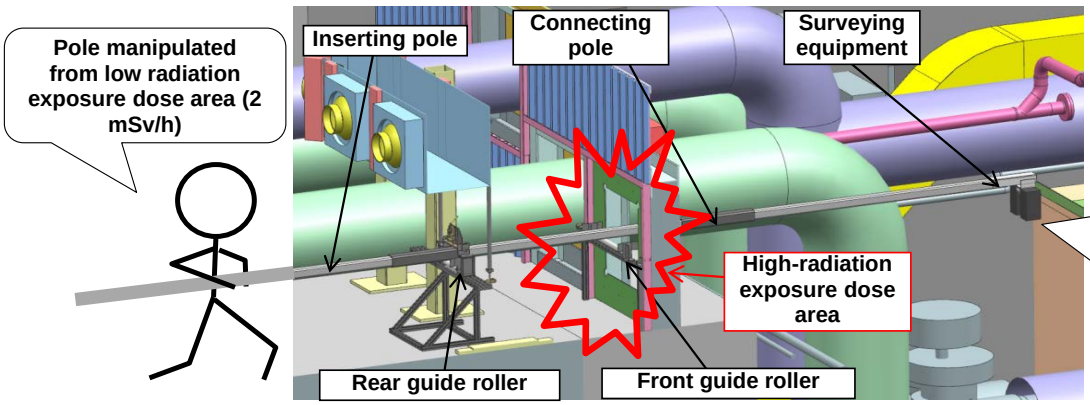
Radiation exposure dose rate inside the room unknown

High radiation exposure dose around the room entrance

Entrance to the room is approximately 4 m from the floor

The room is surveyed by inserting a long pole into the room

- **The surveying equipment was installed at the end of the long pole. Exposure of the worker is reduced by the long distance between end of the pole and the high dose entrance.**



External appearance of the 3D laser scanner

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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	RB	6	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.	28-06

Title	Preventing dust generation when removing rubble (by spraying mist)
Work location	Unit 1 reactor building, 5F (operation floor)
Overview	A mist was sprayed when removing rubble

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	*3,021	*1,278
		Person time (person-days)	8,036	4,088

* Total values of 28-03-1, 28-03-2 and 28-06

Good Practice Description

Before Implementation

There was the risk of dust being generated when removing rubble from the operation floor.

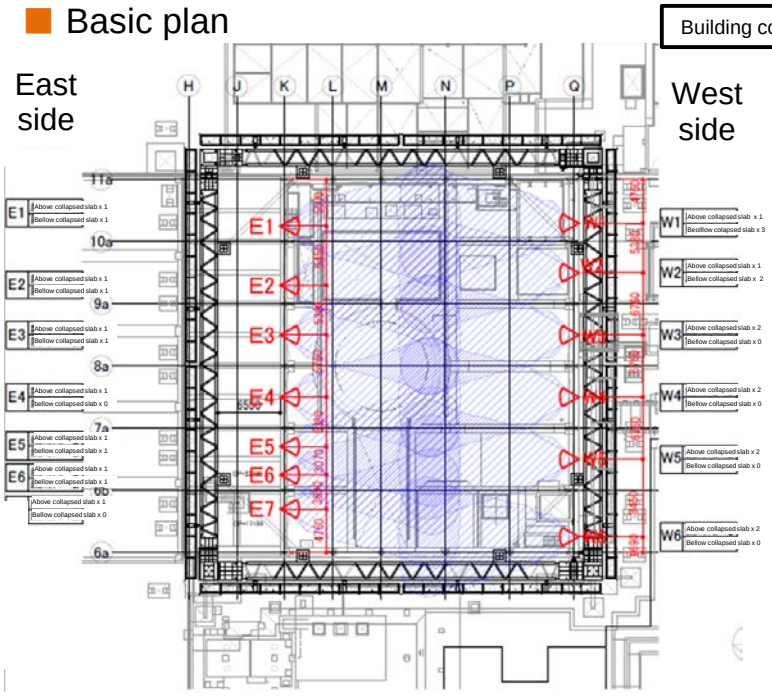
Implementation Details

To prevent dust being generated when removing rubble, equipment was installed to spray mist.

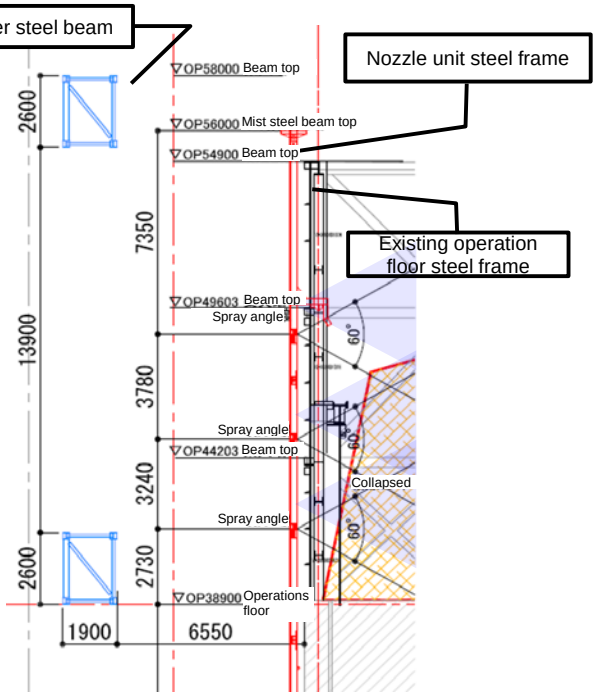
<Mist spraying equipment>

After the building cover was demolished, the rubble pieces that had built up on the reactor building operation floor were removed.
To limit any potential radioactive dust from spreading during the removal of rubble, mist spraying equipment was installed on the existing operation floor steel frame.

■ Basic plan



▲ Mist spraying equipment (nozzles) layout
plan, spraying pattern



▲ Image of nozzle unit steel frame and spray

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Good Practice in Radiation Exposure Dose Reduction Measures;

Location			Category		
Inside reactor building	RB	RB	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.	28-07

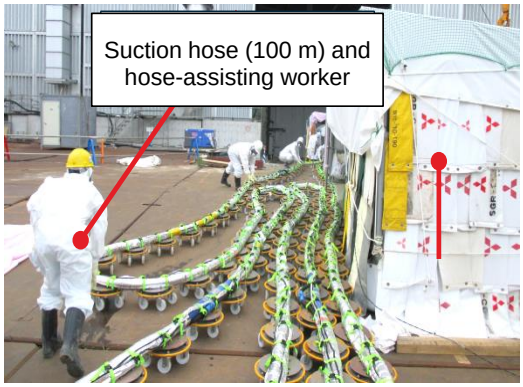
Title	Efficiency improvement of handling suction hose and other assisting operations (improving work method)
Work location	Unit 3 reactor building
Overview	Mounting the suction hoses of decontamination equipment onto trolleys helped to improve suction hose assisting operations

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

Good Practice Description

Before Implementation: Extra assisting operations for the suction hoses when transporting decontamination equipment were resulting in increased exposure dose.

Implementation Details: The suction hoses of decontamination equipment were mounted onto trolleys with casters to improve assisting operations.



Work in progress 1

Suction hoses, trolleys with casters

Work in progress 2

Work in progress 3

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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	TB	1	Time	
Inside turbine building	TB (circled)		2 (circled)	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.	28-08

Title	Ensuring distance by using remote-controlled devices
Work location	Unit 1 turbine building, 1F
Overview	A remote-controlled hydraulic cutter was used to remove impeding rubble in the floor drain pit in the basement of turbine building 1F

Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	*10,079	*2,984
	Person time (person-days)	--	--

* Total values of 28-08 to 10

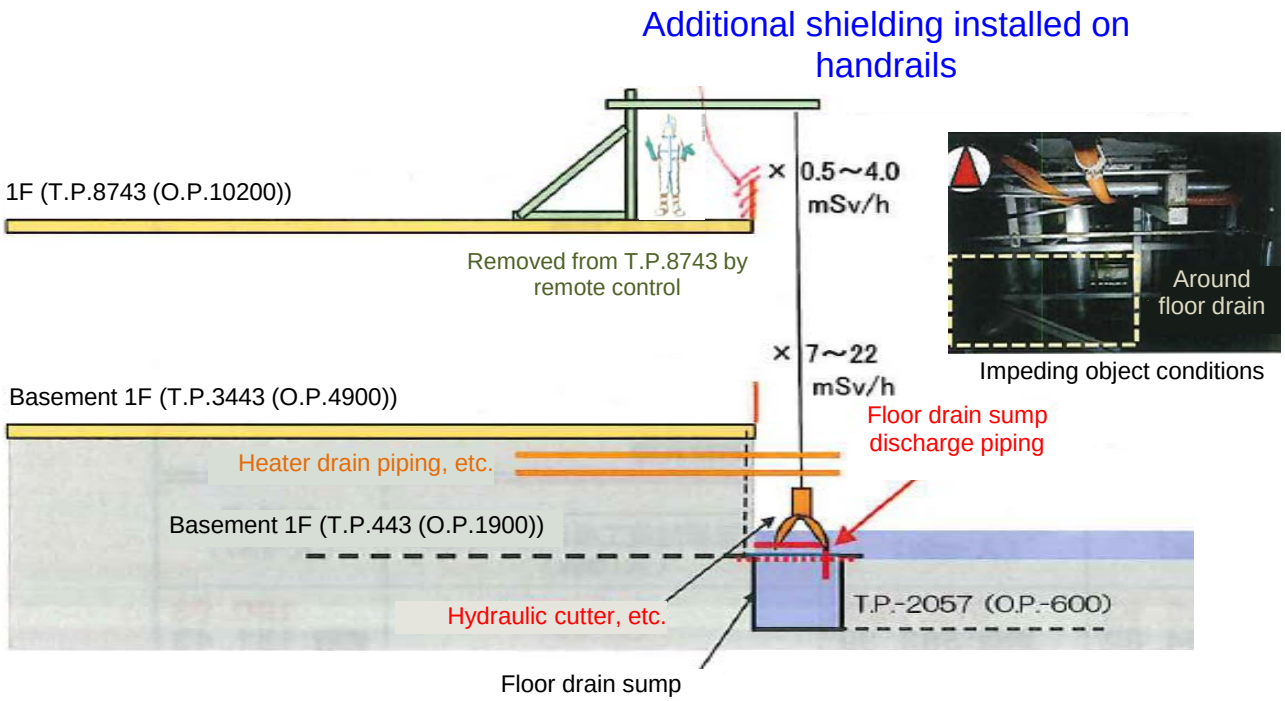
Good Practice Description

Before Implementation

The basement of the turbine building was an area with a high radiation exposure dose rate, and workers removing impeding objects were expected to be subjected to a high exposure dose.

Implementation Details

A remote-controlled hydraulic cutter was used and controlled by workers from areas with a low radiation exposure dose rate on 1F. Additional shielding was installed on the handrail where the workers were located to reduce the environment radiation exposure dose rate there.



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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
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
				7	Other

No.	28-09

Title	Flushing heater drain (HD) piping (removing radiation source)
Work location	Unit 1 turbine building, 1F
Overview	The heater drain (HD) piping that was a radiation source was flushed with cleaning water to remove the radiation source

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	*10,079	*2984
		Person time (person-days)	--	--

* Total values of 28-08 to 10

Good Practice Description

Before Implementation

The unit 1 condenser (including the heater drain piping) was verified to be a high dose radiation source due to the stagnant water stored after the earthquake, which could subject workers to a high exposure dose.

Implementation Details

The water within the condenser and heater drain piping was drained and diluted.

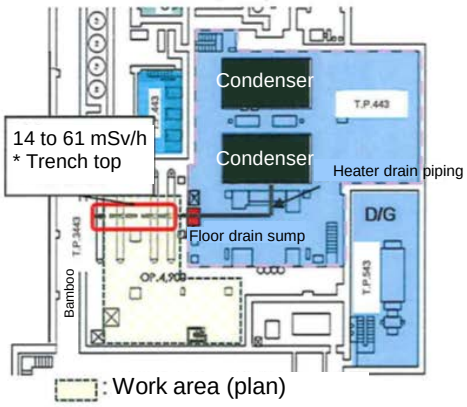
Step 1: install temporary pump inside condenser.

Step 2: partially drain stagnant water within condenser.

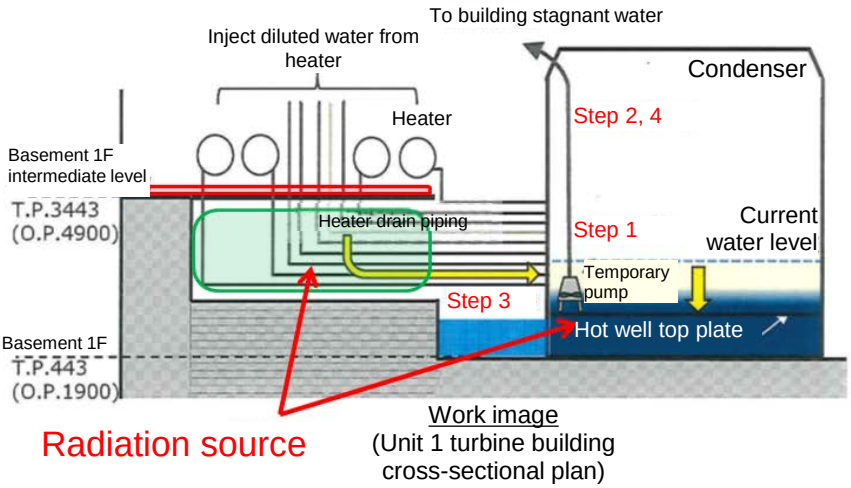
Step 3: inject diluted water from the heater drain piping.

Step 4: drain water within condenser again.

Step 5: repeat steps 3 and 4 several times.



Unit 1 turbine building floor plan



Work image (Unit 1 turbine building cross-sectional plan)

<Note> It is vital to verify the location of the radiation source and treatment location the water used for flushing. (The treatment location could be subjected to a high radiation exposure dose rate)

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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	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

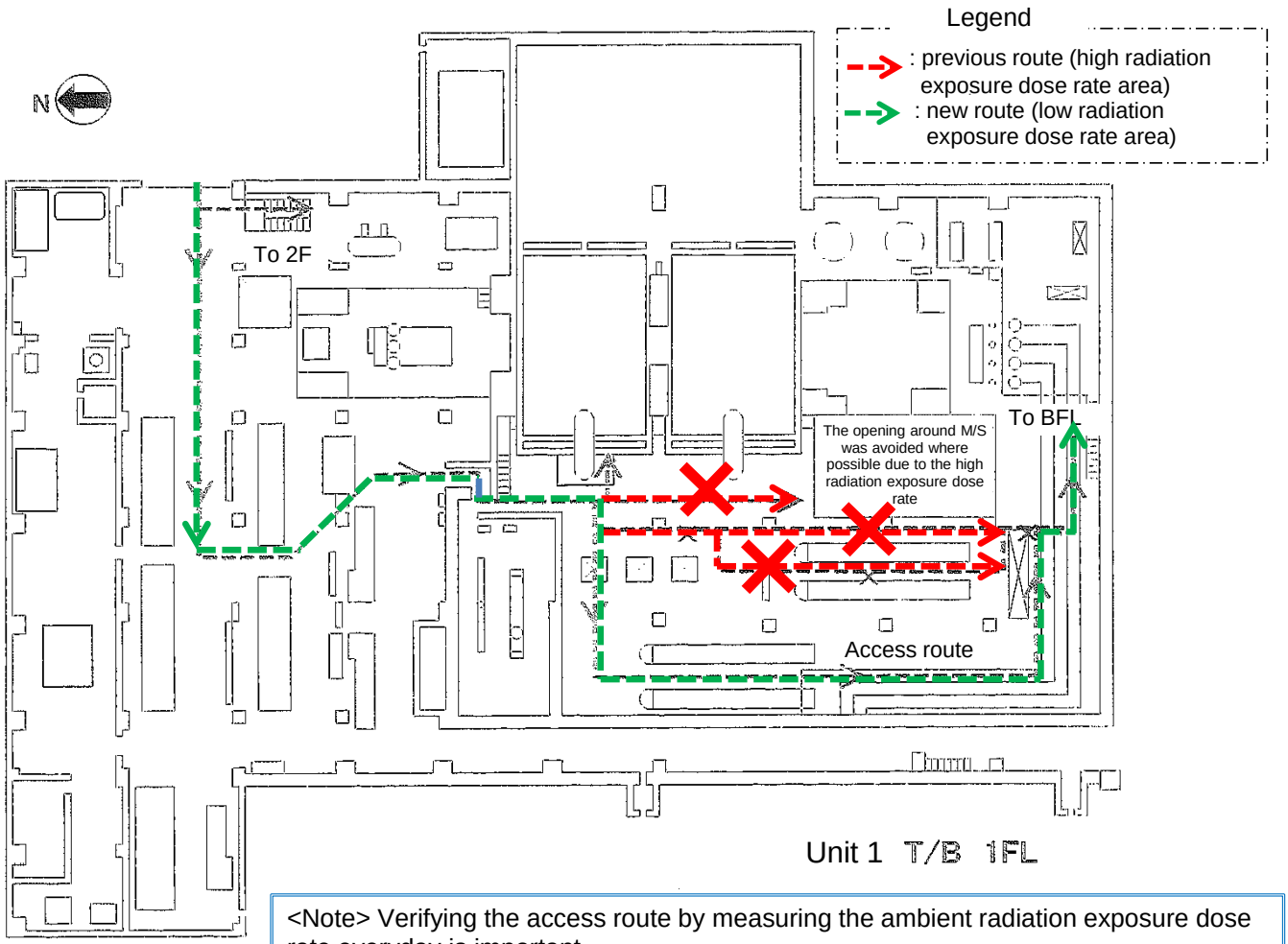
No.	28-10

Title	Changing access routes to low radiation exposure dose rate areas
Work location	Unit 1 turbine building, 1F
Overview	An area with a low radiation exposure dose rate was selected for the route to work areas to reduce exposure dose when moving

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	*10,079	*2,984
		Person time (person-days)	--	--

* Total values of 28-08 to 10

Good Practice Description	
Before Implementation	The route for moving to work areas included sections with a high radiation exposure dose rate, and there was the possibility of increased exposure dose while moving.
Implementation Details	Routes with a high radiation exposure dose rate were avoided, and an area with a low radiation exposure dose rate selected as the access route to work areas to reduce the exposure dose when moving. Workers were also informed of the change.



<Note> Verifying the access route by measuring the ambient radiation exposure dose rate everyday is important.

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Good Practice 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.	28-11

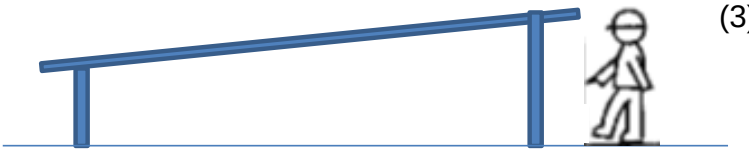
Title	Installing prefabricated shelters off-site to simplify site work (changing work location).
Work location	Around the Unit 3 turbine building backwashing valve pit
Overview	Prefabricated shelters were assembled off-site while installing the cover to the backwashing valve pit to simplify the site work and shorten time

Assessment (qualitative/ quantitative)	Effects		Reduction Amount
		Radiation exposure dose (mSv)	1069
		Person time (person-days)	220

Good Practice Description

Before Implementation: The backwashing valve pit had an ambient radiation exposure dose rate of around 2.9 mSv/h due to the surrounding rubble, and there was the possibility of a high radiation exposure dose while installing the pit cover.

Implementation Details: Cover materials were prefabricated (assembled) off-site to be moved and installed as assembled, in order to simplify work around the backwashing valve pit and shorten the time required.



(1) Roof and pillar assembled and temporarily mounted off-site (outside control zones)
(2) This achieved the same effects as the mockup.
(3) Transported cover materials to the site

Off-site work (photos)

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Good Practice 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.	28-12

Title	Installing shielded booth
Work location	Units 1 to 4 seaside area
Overview	A shielded booth was installed for management staff to reduce their exposure dose

Assessment (qualitative/ quantitative)	Effects		Reduction Amount
		Radiation exposure dose (mSv)	66
		Person time (person-days)	--

Good Practice Description

Before Implementation	Management staff were always monitoring work from an on-site location. Staying in an area with a relatively low radiation exposure dose rate for a long period of time increased their exposure dose.
Implementation Details	A shielded booth was installed for management staff, where they could spend time for duties other than site management, to reduce their exposure dose.

1. A lead-shielded booth was installed for management staff where they could spend 50% of their work time (effect of lead shielded booth: approximately 50%)

2. Expected effects

(1) Workers: 2 people × 100 days = 200 person-days

(2) Work environment radiation exposure dose rate: amount of reduction 20 person-mSv

Before: 0.10 mSv/h 4 hours × 200 person-days = 80 person-mSv

After: (0.10 mSv/h × 2 hours) + (0.05 mSv/h × 2 hours) × 200 person-days = 60 person

Lead-shielded standby booth

<Note> It is important to determine and install a shielded booth commensurate with the number of workers who will be using it.

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Good Practice 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	Removing radiation source
Other ( )	Z		6	Removing radiation source
			7	Other

No.	28-13

Title	Utilizing shielded boxes from other work (improving work method)
Work location	Outside Unit 3 reactor building
Overview	Utilizing shielded boxes from other work (improving work method)

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

Good Practice Description

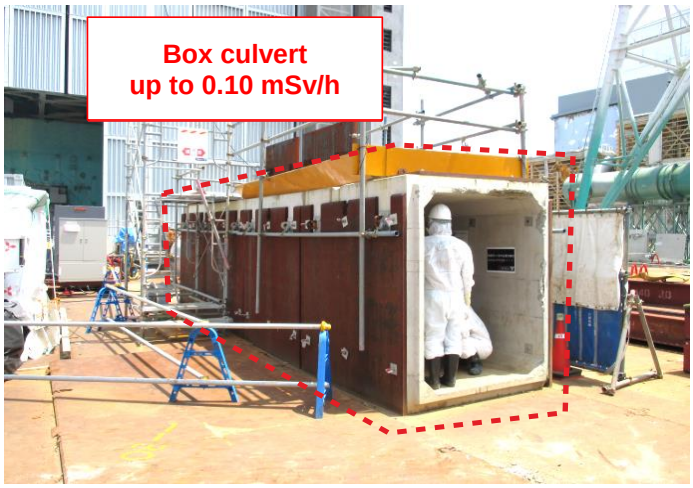
Before Implementation Temporary shielded booths were installed, however their shielding was not as effective as expected due to a high radiation exposure dose from above.

Implementation Details Work processes were adjusted so that box culverts near the work area that had been installed and used for other work could be utilized as shared evacuation shelters. A daily usage schedule was also created to avoid crowding.

Before implementation

No shielding in ceiling of temporary shielded booth.

After implementation



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Good Practice 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.	28-14

Title	Clearly display radiation exposure dose at work areas
Work location	Side of turbine building
Overview	Show high-radiation exposure dose positions in work areas to make workers aware of the radiation exposure dose rate.

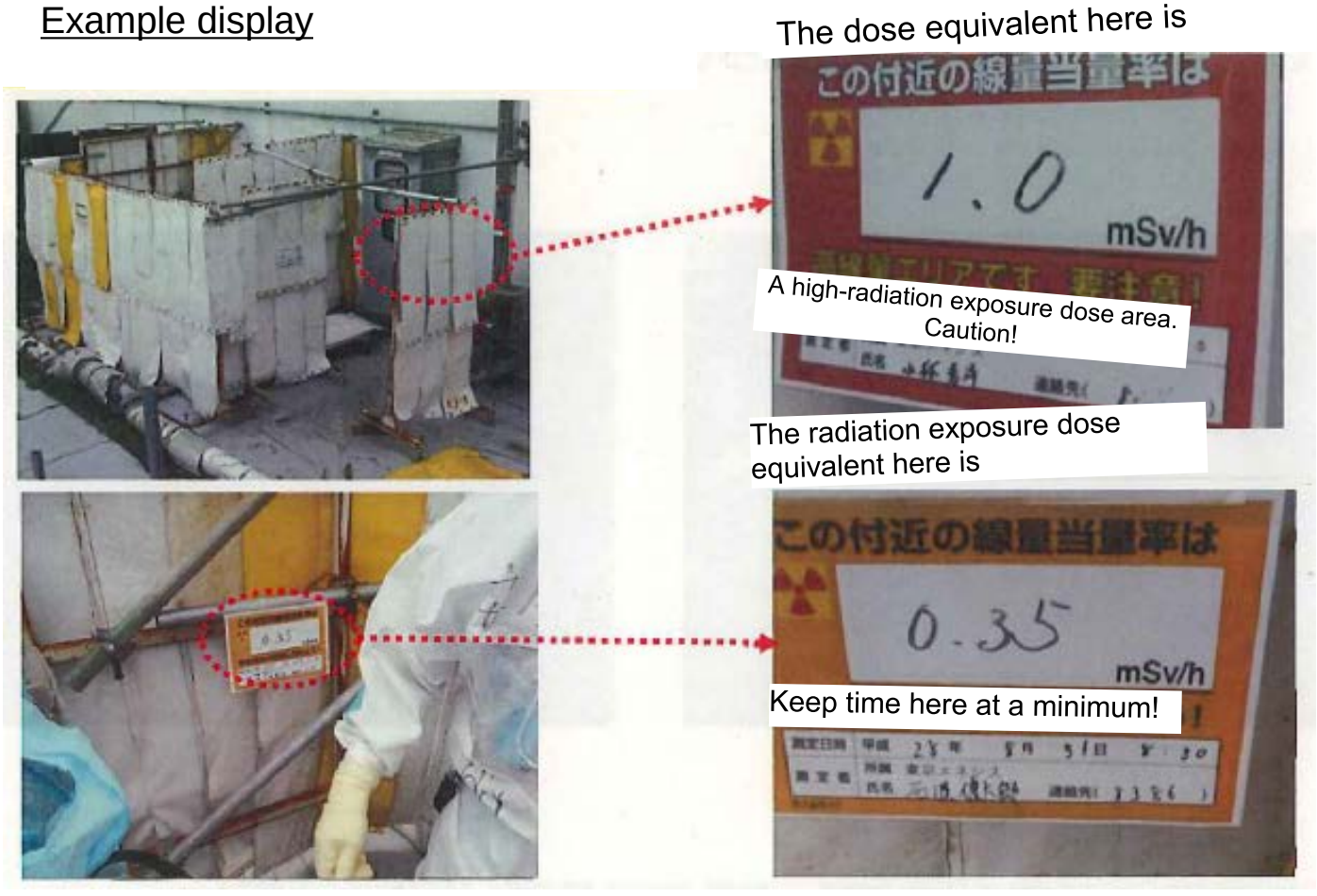
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

Before Implementation: No display of radiation exposure dose, meaning there was a possibility that workers could be subjected to unnecessary exposure in high-radiation exposure dose locations.

Implementation Details: High-radiation exposure dose areas are clear, meaning low-radiation exposure dose areas could be utilized to reduce workers' exposure dose.

Example display



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Good Practice 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	7	4	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			(7)	Other

No.	28-15

Title	Reducing site work by using existing structures (improving work method)
Work location	Around the Unit 3 turbine building backwashing valve pit
Overview	Instead of making a foundation on which to install the cover material, the pit enclosure was used as the foundation (improving work method)

Assessment (qualitative/ (quantitative))	Effects		Reduction Amount
		Radiation exposure dose (mSv)	553
		Person time (person-days)	--

Good Practice Description

Before Implementation

The backwashing valve pit had an ambient radiation exposure dose rate of up to 2.9 mSv/h due to the surrounding debris, and there was the possibility of a high radiation exposure dose while making the foundation for installing the pit cover.

Implementation Details

The existing backwashing valve pit enclosure was used as the foundation to install the cover material, eliminating the need to construct a foundation (improving work method).

Directly place the cover on the pit enclosure

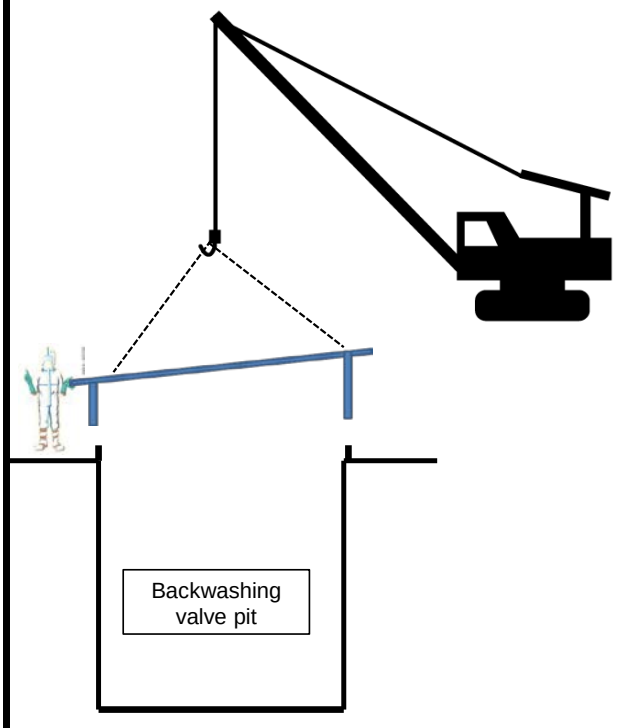
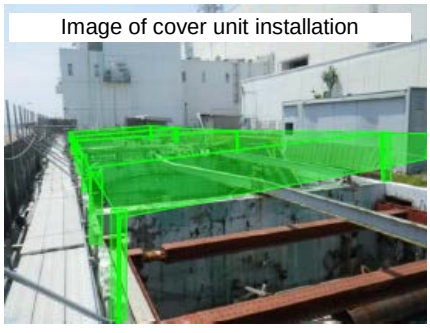
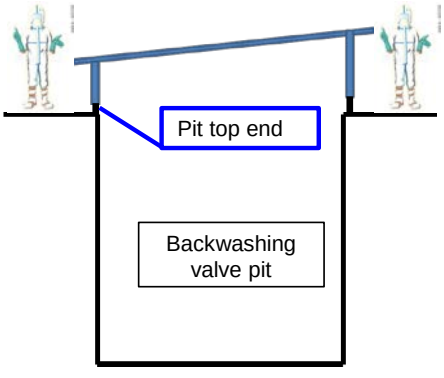


Image of cover unit installation





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Good Practice 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.	28-16

Title	Changing excavator bucket installation orientation
Work location	Slope on site
Overview	Excavator buckets were installed in reverse to normal when stripping the soil, to improve work efficiency

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

Good Practice Description

Before Implementation Using ordinary excavators to strip the soil on the slope was expected to result in poor work efficiency and take longer.

Implementation Details The excavator bucket was installed in reverse to make it easier to strip soil from the slope.

The bucket was modified to make stripping soil from the slope easier.
Work time was reduced by using an excavator suited to site conditions.

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Good Practice 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.	28-17

Title	Shielding surveying machinery control room
Work location	Unit 4 Seaside area
Overview	Shielding methods developed using lead wool mats

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

Good Practice Description

Before Implementation The dose rate in the surveying machinery control room was 70 μSv/h due to γ rays from the ground and turbine side.

Implementation Details Lead wool mats, crushed stone and iron plates were installed in the direction of each radiation source (turbine side and ground) to provide shielding.

- Installing lead wool mat shielding against radiation from the turbine building reduced the ambient radiation exposure dose rate from 70 μSv/h → 25 μSv/h (by approximately 60%).
- Shielding against radiation from the ground was achieved using crushed stone and iron plates.

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Good Practice 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.	28-18

Title	Sheet covering during removal and storage of contaminated soil
Work location	Slope on site
Overview	Stripped soil was covered by sheets when placing the soil in sandbags

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

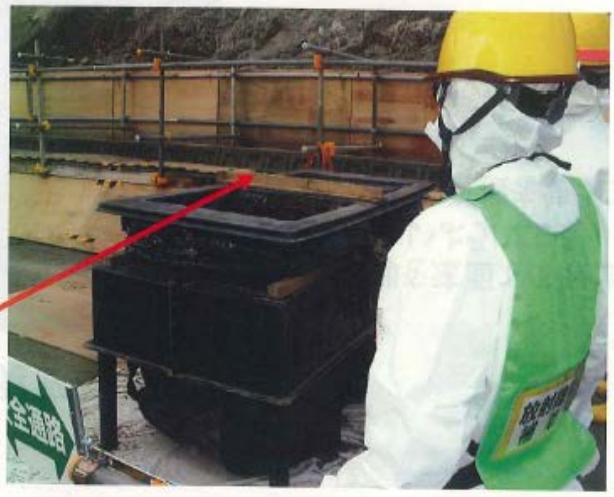
Good Practice Description

Before Implementation
Soil stripped using an excavator bucket was spreading contamination when being placed in bags, as the contaminated soil scattered around the sandbags.

Implementation Details
A sheet was placed under the sandbag filling equipment to prevent contaminated soil from scattering.

Wood was used to prevent sandbags from being damaged due to rocks or other objects

The sheet under the sandbag equipment helped prevent the spread of contamination and damage to sandbags



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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	RB	G	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.	28-19

Title	Topographic surveying of inclined ground using drones
Work location	Sloped areas on site
Overview	Surveying work conducted prior to repairing slopes was changed from manual labor to drone aerial photos

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	13.5	0.5
		Person time (person-days)	270	24

Good Practice Description

Before Implementation: Safety rope anchors were installed so that numerous staff could work safely on the slope to conduct surveys. (Work period...approximately 30 days)

Implementation Details: The use of drones meant that surveying control points and operating the drones was required, resulting in shorter work period. (Work period...approximately 5 days)

Drone main unit

Controller

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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	G	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.	28-20

Title	Providing rest facilities
Work location	1F off-site area
Overview	Providing rest facilities near work location

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

Good Practice Description

Before Implementation: The work area was located off-site on 1F; however, the rest area was on-site on 1F, with the distance resulting in exposure doses.

Implementation Details: Rest facilities were installed near work location.

Break room

Body survey room

Air-conditioning and local ventilation

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Good Practice in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	G	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.	28-21

Title	Mechanization of mowing work
Work location	1F on-site flat and sloped land
Overview	Machines are used for mowing work on the site that was previously cut by hand

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	12	2.5
		Person time (person-days)	240	62

Good Practice Description

Before Implementation

Motorized mowers were used to cut grass by hand.

Implementation Details

A mower unit was mounted to an excavator and used to cut the grass, reducing labor hours.

Mowing on flat land

Mowing on sloped area

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Location			Category		
Inside reactor building	RB	G	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 Practice in Radiation Exposure Dose Reduction Measures

No.	28-22

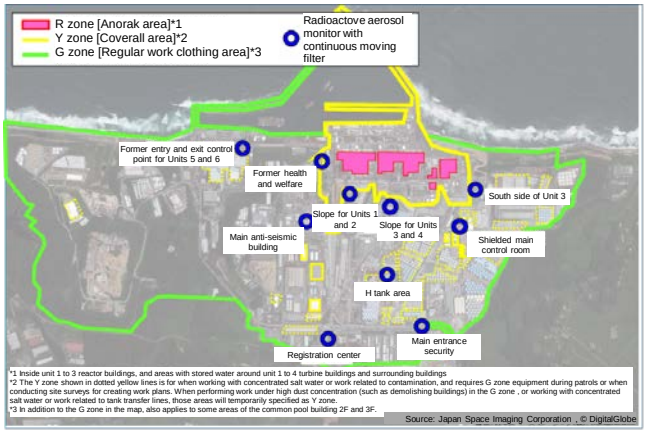
Title	Reducing the amount of protective equipment worn with more detailed site zones
Work location	All yard green zones
Overview	As part of decontamination efforts across the site, zones were classified into high-dose areas and other areas

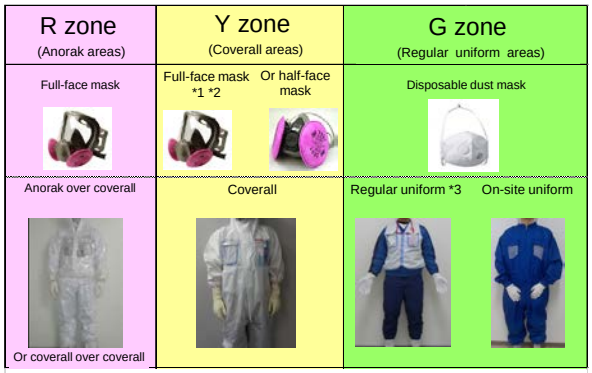
Assessment (qualitative/ quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	--
	Person time (person-days)	--	--

Good Practice Description

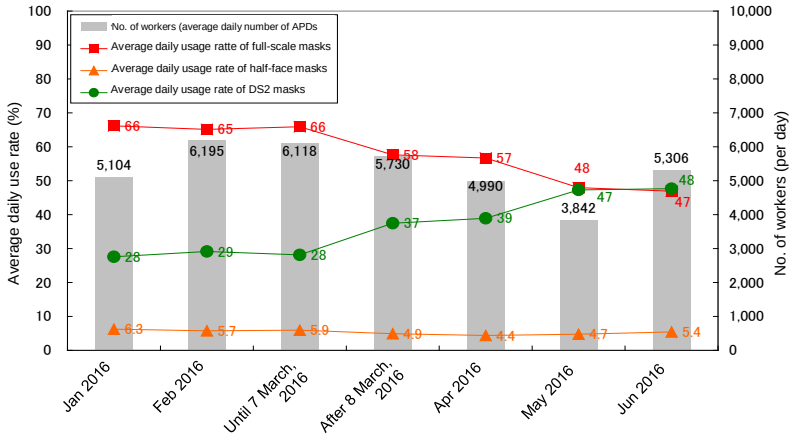
Before Implementation Contamination categories were not assigned thoroughly for required work equipment, resulting in workers wearing more equipment than necessary, increasing their workload and reducing work efficiency.

Implementation Details Categorizing the work equipment for each contamination zone reduced the protective equipment and workload of workers, improved work efficiency and reduced their exposure dose.





*1 For work performed inside buildings of Units 1-4 and surrounding buildings, including water treatment facilities such as multi-nuclide removal facilities (excluding observation visits), full-face masks are to be worn.
*2 For work performed around tanks containing contaminated water, for example, concentrated salt water or strontium treated water (excluding work that does not involve the handling of concentrated salt water, field surveys in the work planning phase, patrolling, observation visits, etc.), and work that involves the handling of transport lines to tanks, full-face masks are to be worn.



Full-face mask, half-face mask, and DS2 usage

●After the new zoning application, the average daily use rate of full-face masks has decreased from about 66% to about 47% and the average daily use rate of disposable dust masks (DS2) has increased from about 28% to about 48%.

●These changes indicate reductions in protection level that equipment must provide from full-face masks to DS2 masks. (This resulted in better work efficiency)

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Good Practice in Radiation Exposure Dose Reduction Measures

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 (main process building)	Z		6	Preventing spread of contamination	
			7	Other	

No.	28-23

Title	Conducting mockup training
Work location	Main processing building route
Overview	A situation similar to the actual working environment was reproduced to reduce the operation time

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

Good Practice Description

Before Implementation: Shortening work time is essential for reducing exposure dose.

Implementation Details: Mockup training of the actual area was conducted to help shorten work time.

Mockup training

・A situation similar to the actual working environment was reproduced to reduce the operation time.

<Note> It is vital to reproduce all aspects, such as worker assignment, movement, equipment handling processes and worn protective equipment as close as possible to the actual work.

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

Good Practice in Radiation Exposure Dose Reduction Measures

No.	28-24

Title	Changing work location (assembly work at low dose rate areas)
Work location	Main processing building route
Overview	Equipment was assembled in areas with a low radiation exposure dose, and transported and installed with a crane after assembly to help reduce the exposure dose

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

Good Practice

Before Implementation: The equipment was installed in a high radiation exposure dose area, and assembling the equipment there would result in a high exposure dose.

Implementation Details: Equipment was assembled in areas with a low radiation exposure dose, and transported and installed with a crane after assembly.

Assembly work at low dose rate areas

・Assembly of the pump unit takes time (8 days). From the construction planning stage, a method to install the unit after assembling it in a low dose rate area was considered and implemented.

Assembled in a low dose rate area
(0.07 mSv/h)

Moved using a crane

Installed in a high dose rate area
(5 mSv/h)

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Location			Category		
Inside reactor building	RB	Z	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 (main process building)	(Z)			6	Preventing spread of contamination
				7	Other

Good Practice in Radiation Exposure Dose Reduction Measures

No.	28-25

Title	Shielding and partitioning transportation routes with a high radiation exposure dose rate
Work location	Main processing building route
Overview	Shielding in high radiation exposure dose rate routes, partitioning of high radiation exposure dose rate areas and clearly displaying the direction of movement were used to help reduce exposure doses as much as possible while moving

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	44.5
		Person time (person-days)	--	--

Good Practice Description

Before Implementation Shielding was required against the γ radiation source at the center of the pit area.

Implementation Details L-shaped shielding was installed along routes to halve the ambient radiation exposure dose rate, and partitioning and directions were displayed clearly (visualization) to prevent accidental entry into high radiation exposure dose areas.

(1) L-shaped temporay shielding installed

Dose rate contribution from the main radiation source at the central part of the pit was reduced

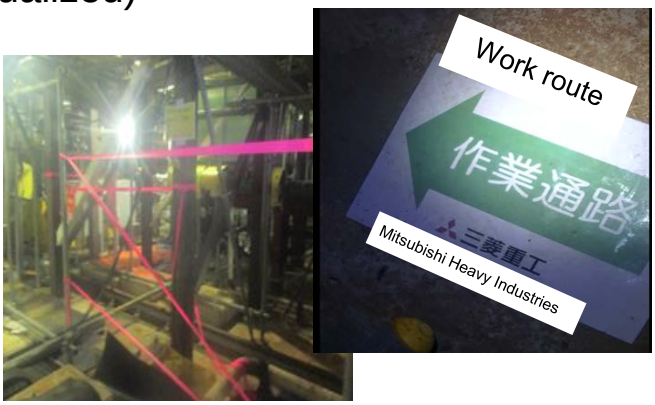
(**10.0 mSv/h → 5.0 mSv/h**)

L-shaped temporary shielding

(2) Travel path sectioned (visualized)

・To prevent accidental travel through high dose rate areas, the travel path was sectioned using tapes

・To prevent unnecessary exposure while travelling, travel direction was clarified using arrows



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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 (main process building)	(Z)		6	Preventing spread of contamination
			7	Other

Good Practice in Radiation Exposure Dose Reduction Measures

No.	28-26

Title	Monitoring using remote-control cameras/installing area monitors
Work location	Main processing building route
Overview	Instead of supervisors attending worksites to give work instructions, remote-control cameras were used to provide instructions and monitor readings from the area remotely

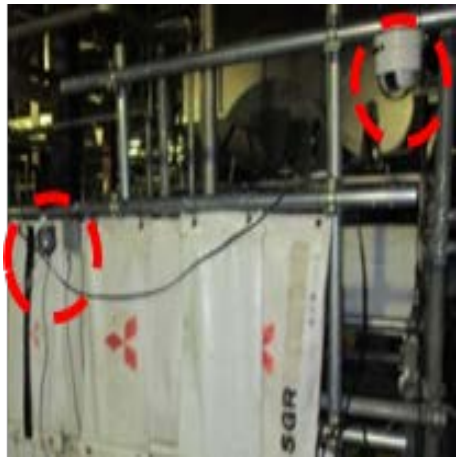
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description

Before Implementation: Supervisors used to attend worksites to give work instructions, resulting in high exposure doses amongst supervisors.

Implementation Details: To reduce the amount of exposure for supervisors, work instructions were provided from the control office outside the building, and remote monitoring cameras and radiation monitors installed.

Remote-control camera/area monitor



Installation of remote-control cameras

Installation of area monitor

Checking the work site through a monitor screen

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Good Practice in Radiation Exposure Dose Reduction Measures

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 (unit 5, 6 service buildings)	(Z)		(6)	Preventing spread of contamination	
			7	Other	

No.	28-27

Title	Preventing contamination from being brought in
Work location	Unit 5, 6 service buildings (S/B)
Overview	The S/Bs were in low-contamination areas, and measures were introduced to prevent contamination being brought in as well as to ensure thorough cleaning, to help improve work efficiency and reduce work equipment

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

Good Practice Description

Before Implementation

Access to the S/Bs required a change of boots to prevent outside contamination being brought in; however, there were concerns about the possibility of outside contamination being brought in due to the major increase in number of workers accessing the building.

Implementation Details

Changing boots and thorough cleaning/partitioning was used to prevent contamination being brought in.

Reduce physical load

・Prevented contamination being brought in, and reduced the work equipment for installing new equipment (using N95 dust mask)
・Installed a rest area inside work area (on-site cooler)

Effects: construction proceeded during summer, but no workers reported heat stroke

Prevent bodily contamination

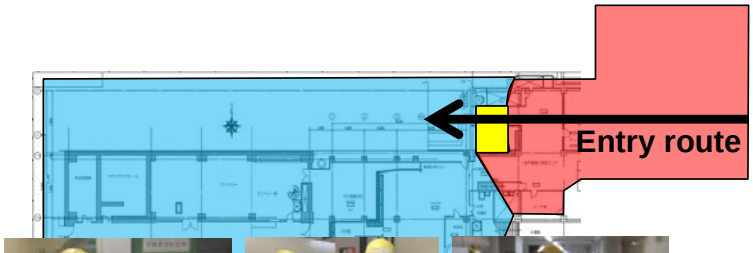
・Changing boots and thorough cleaning/partitioning

Effects: no major bodily contamination reported during the construction period

Preventing spread of contamination

・Changing boots and thorough cleaning/partitioning
・Prevented spread of contamination with clean house and local ventilation

Effects: no spread of contamination throughout work area, no returning for decontamination required




Tool checks


Physical checks


Cleaning routes

<Note>
Checking by verifying the contamination every day is important.

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Good Practice in Radiation Exposure Dose Reduction Measures

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 (main process building)	Z		6	Preventing spread of contamination	
			7	Other	

No.	28-28

Title	Preventing internal exposure by wearing two layers of masks
Work location	Main processing building route
Overview	A full-face mask and hooded mask were required to prevent internal exposure of workers

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

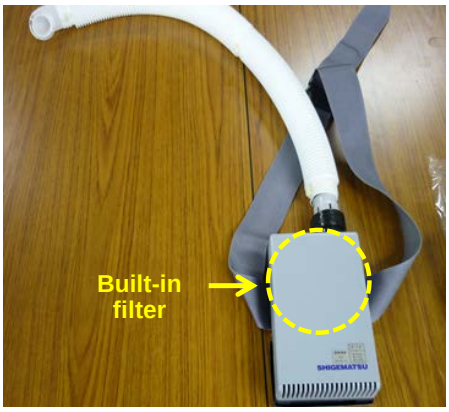
Good Practice Description

Before Implementation: Wearing a full-face mask to work sites resulted in high-level contamination collected in dust filters, introducing the risk of internal exposure.

Implementation Details: To prevent internal exposure, workers were required to wear a hooded mask over the full-face mask in a two-layer arrangement.

Wearing two layers of masks (full-face and hooded masks)

- To ensure the prevention of internal exposure, a dual-filter system was adopted (full-face mask filter + AP-60 filter)



Blower with filter (AP-60)

+

Special hooded mask (HD-EFS)

AP-60 equipped

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Column
- Greater sense of safety amongst workers -

"Safety First/Measures to Reduce Exposure...OK!"

I had a weird sense when I first saw this photo. "What's that for?"
After thinking about it for a while, I saw that this was actually an act of love.
"What were they thinking when they wrote it? And who did they write it for?
Loving your home town, your company, your friends, and of course your family..."
I'm sure that all of these apply.

The photo also indicates how difficult this decades-long process will be to achieve "without injury, without exposure."
The only response is... "Safety First!"

(by S.K)

Safety First

Safety First
Measures to
Reduce
Exposure...OK!!

1F - Unit 1 Reactor Building 5F Suction of rubble pieces such as roof blocks using large rubble suction machine

Source: Shimizu Corporation

Good Practices in Radiation Exposure Dose Reduction Measures

Published February 2017
Commissioned by the Ministry of Health, Labour and Welfare in FY2016
"Project to Enhance the International Transmission of Radioactivity-Related Information on the Workers at TEPCO Holdings' Fukushima Daiichi Nuclear Power Plant"
Trustee: Japan Environment Research Co., Ltd.