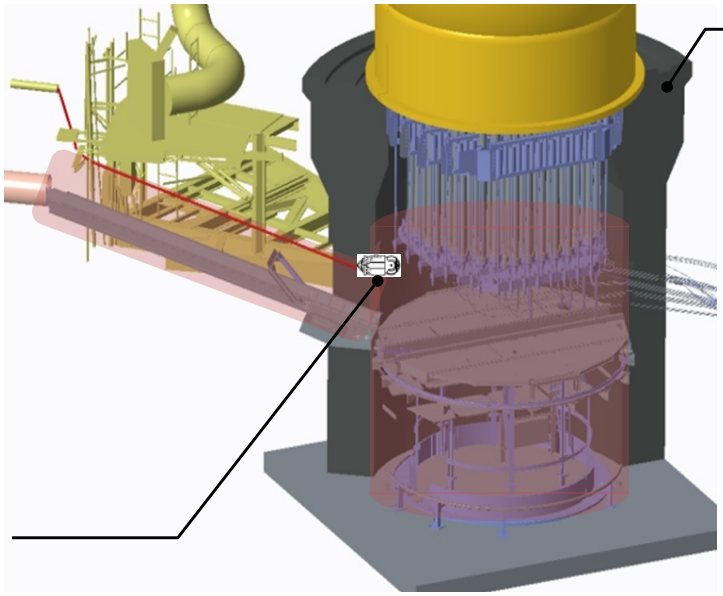
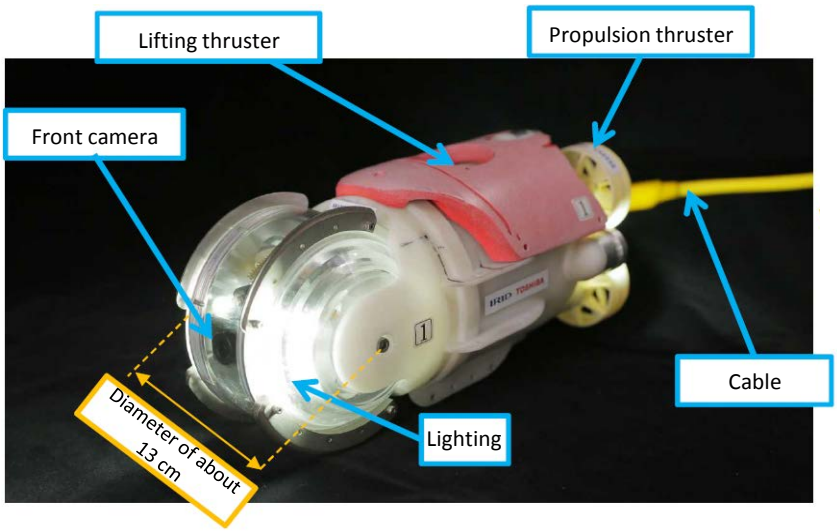
Commissioned by the Ministry of Health, Labour and Welfare in FY2017
Project to Enhance the International Transmission of Radioactivity-Related Information
on the Workers at TEPCO Holdings' Fukushima Daiichi Nuclear Power Plant

Good Practices in Radiation Exposure Dose Reduction Measures





"Unit 3 Reactor: How to Reduce Exposure Dose during Internal Investigation of Reactor Containment Vessel, and Removal and Installation of Fixed Thermometer" (Material provided by Toshiba Energy Systems & Solutions Corporation)

This includes results achieved by the International Research Institute for Nuclear Decommissioning and Toshiba Energy Systems & Solutions Corporation with a FY2015 subsidy for decommissioning and contaminated water management (for developing techniques for investigating the inside of reactor containment vessel).

Edited: Japan Environment Research Co., Ltd.

Contents List of Good Practices in Radiation Exposure Dose Reduction Measures

No.	Location	Category	Title	Radiation exposure dose equivalent (mSv)			Notes
				Before implementation	After implementation	Reduction amount	
29-01-01	RB	3	Shielding the front of X-6 of Unit 2 reactor building	--	--	--	
29-01-02	RB	3	Shielding the front of X-6 of Unit 2 reactor building	--	--	--	Shielded so the air dose rate becomes 1/1000 of the original value.
29-02-01	RB	5	Adopting the remote monitoring system	1.0	0.87	--	Relative value
29-02-02	RB	5	Adopting the remote monitoring system	1.0	0.87	--	Relative value
29-02-03	RB	5	Configuring the remote monitoring system	--	--	119	
29-03	RB	6	Preventing contamination of insertion apparatus when pulling it out of the PCV	--	--	77	
29-04-01	TB	2	Changing the work place to an area with a low radiation exposure dose rate	7 to 22	0.5 to 4.0	--	
29-04-02	TB	5	Changing the work place to an area with a low radiation exposure dose rate	7 to 22	0.5 to 4.0	--	
29-05-01	TB	3	Shielding heater drain piping and other parts	5.6	1.6	--	
29-05-02	TB	3	Shielding heater drain piping and other parts	--	--	--	
29-06	TB	3	Shielding the accessible area of the upper part of the condenser	--	--	--	
29-07	TB	3	Shielding the transfer lines of water stored in the condenser	--	--	--	
29-08	TB	3	Shielding the opening around the condenser	2.4	1.4	--	
29-09-01	TB	3	Installing pre-assembled partitioning shields	2.8	0.11	--	
29-09-02	TB	3	Installing pre-assembled partitioning shields	2.8	0.11	--	
29-10-01	TB	5	Removing accumulated sludge	--	--	--	
29-10-02	TB	4	Removing accumulated sludge	--	--	--	
29-11	TB	4	Diluting the water with a high radiation exposure dose rate that was stored in the condenser	--	--	--	Diluted until the amount of radioactive substances inside the condenser becomes 1/30 of the original value.
29-12	TB	7	Setting and indicating the access route	--	--	--	
29-13	R	2	Setting lifting facilities in areas with a low radiation exposure dose rate	--	--	--	
29-14	R	2	Setting traffic lines and waiting areas at places with low radiation exposure doses	1.0	0.46	--	Relative value
29-15	R	3	Shielding the periphery of Unit 3 reactor building	1.0	0.30	(228)	Relative value
29-16	R	3	Shielding for radioactive substances from the upper part of Unit 3 turbine building	--	--	--	
29-17	R	3	Shielding for beta rays inside the flange tank	89.4	2.4	--	
29-18	R	3	Adopting shielding trolleys	1.0	0.46	--	Relative value
29-19-01	R	4	Removing rubble before applying waterproof coating	--	--	--	
29-19-02	R	4	Removing rubble before applying waterproof coating	--	--	--	
29-20	R	5	Using a remote sprayer to control spreading of the contamination on the inner surface of the tank	42.3 per tank	0 per tank	42.3 per tank	
29-21	R	6	Contamination management during flange tank disassembly	--	--	--	
29-22	R	7	Reducing workload by developing and using the superfluid concrete material	1.0	0.25	--	Relative value
29-23	R	7	Mechanizing waterproof coating	1.0	0.46	--	Relative value

Note: The above good practices have been taken from the Radiation Exposure Dose Reduction Measures Workshop held on November 9, 2017, and then edited.

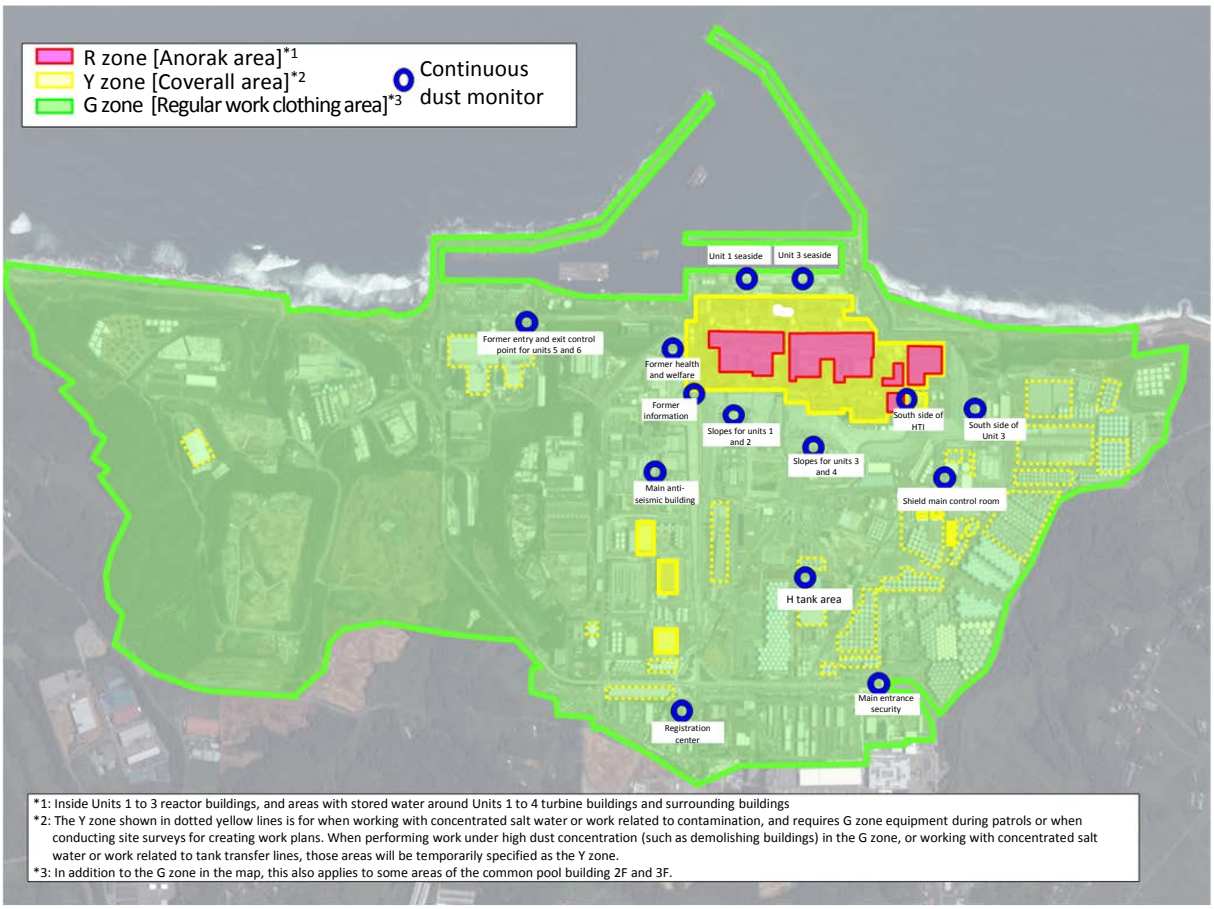
1F Site Operation Zone Control

(1) 1F site operation zone status

Zone		Protective Equipment
Red zone (Anorak areas) - Inside Units 1 to 3 reactor buildings - Area with stored water around Units 1 to 4 reactor buildings		- Full-face mask - 2 layer coveralls or anorak - Work boots (for R zone) - Helmet (for R zone) - Cotton gloves + rubber gloves
Yellow zone (Coveralls areas)	- Inside buildings that include water treatment facilities (such as desalinization 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 - Coveralls - Work boots (for Y zone) - Helmet (for Y zone) - Cotton gloves + rubber gloves
	- Around Units 1 to 4 buildings - Specified as required to suit work environment (such as inside Units 5, 6 buildings, parts of storage areas for high-radiation exposure dose rubble)	- Half-face mask - Coveralls - Work boots (for Y zone) - Helmet (for Y zone) - Cotton gloves + rubber gloves
Green zone (Regular uniform areas) Areas except the above. Y areas of the following have been changed to G from March 30, 2017: some parts of the periphery of Units 1 to 4 buildings and their slopes.		- D2 mask - Site clothing, regular work clothing*3 - Work boots (for G zone) - Helmet (for G zone) - Cotton gloves + rubber gloves or work gloves
- Inside important anti-seismic buildings and inside rest areas		

*1: 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



Source: Japan Space Imaging Corporation, ©DigitalGlobe

As of Feb. 5, 2018. Material provided by Tokyo Electric Power Company Holdings, Incorporated.

Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-01-01

Title	Shielding the front of X-6 of Unit 2 reactor building
Work location	The front of the 1F X-6 of Unit 2 reactor building
Overview	A shielding body having an optimal shape has been installed for the X-6 penetration part that has a dose rate > 10 Sv/h to perform internal observation of the PCV from the X-6 penetration part.

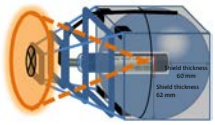
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

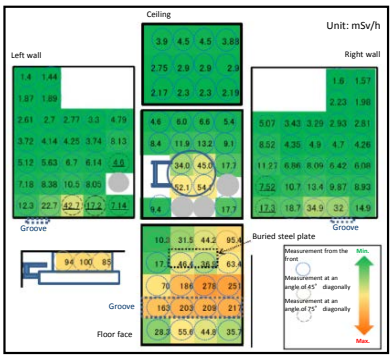
Good Practice Description

Before Implementation
The X-6 penetration part with a high radiation exposure dose rate required a lighter shielding body with an optimal shielding effect.

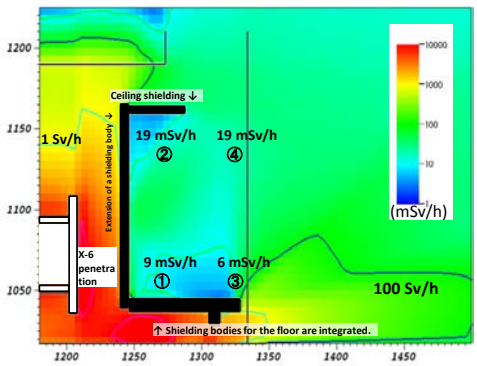
Implementation Details
The radiation exposure rate of the X-6 penetration part was measured in detail for 3D simulation calculation, and a shielding body having an optimal shape has been produced and installed.

Understanding radiation source intensity





3D simulation calculation



Detailed calculation of the radiation exposure dose with a lead collimator

↓

An accurate radiation source model

↓ Quality of shielding calculation and assessment improves.

Repetition of 3D calculation to obtain the optimal shielding

↓ Necessary parts and thickness become clear in detail.

The radiation exposure dose of 20 mSv/h or lower is achieved with the 3-ton shielding.

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Good Practices in Radiation Exposure Dose Reduction Measures

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

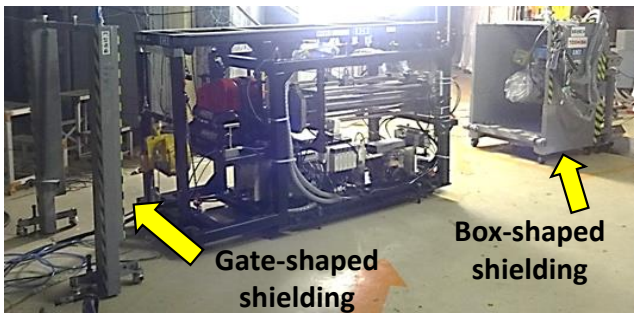
No.	29-01-02

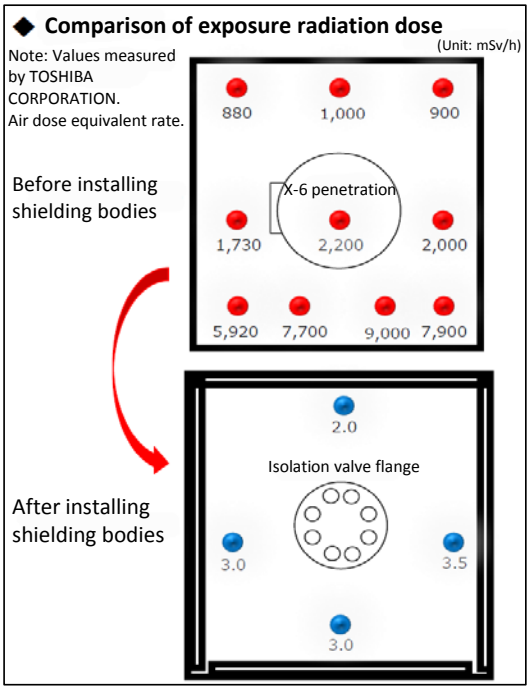
Title	Shielding the front of X-6 of Unit 2 reactor building
Work location	The front of the 1F X-6 of Unit 2 reactor building
Overview	A shielding body having an optimal shape has been installed for the X-6 penetration part that has a dose rate > 10 Sv/h to perform internal observation of the PCV from the X-6 penetration part.

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

Good Practice Description	
Before Implementation	The X-6 penetration part with a high radiation exposure dose rate required a lighter body with an optimal shielding effect.
Implementation Details	The radiation exposure rate of the X-6 penetration part was measured in detail for 3D simulation calculation, and a shielding body having an optimal shape has been produced and installed.

Detailed shielding effect





In addition to the box-shaped shielding obtained by the 3D simulation result, a gate-shaped shielding has been installed to shield the clearance.
Air dose rate (geometric mean value) **2,700 mSv/h → 2.8 mSv/h (reduction of about 1/1000)**

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-02-01

Title	Adopting the remote monitoring system
Work location	Areas with a high radiation exposure dose rate such as reactor buildings
Overview	The remote monitoring system made in the U.S. has enabled the primary contractor to manage and monitor the workers without entering the areas with a high radiation exposure dose rate.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0	Relative value of 0.87
		Person time (person-days)	--	--

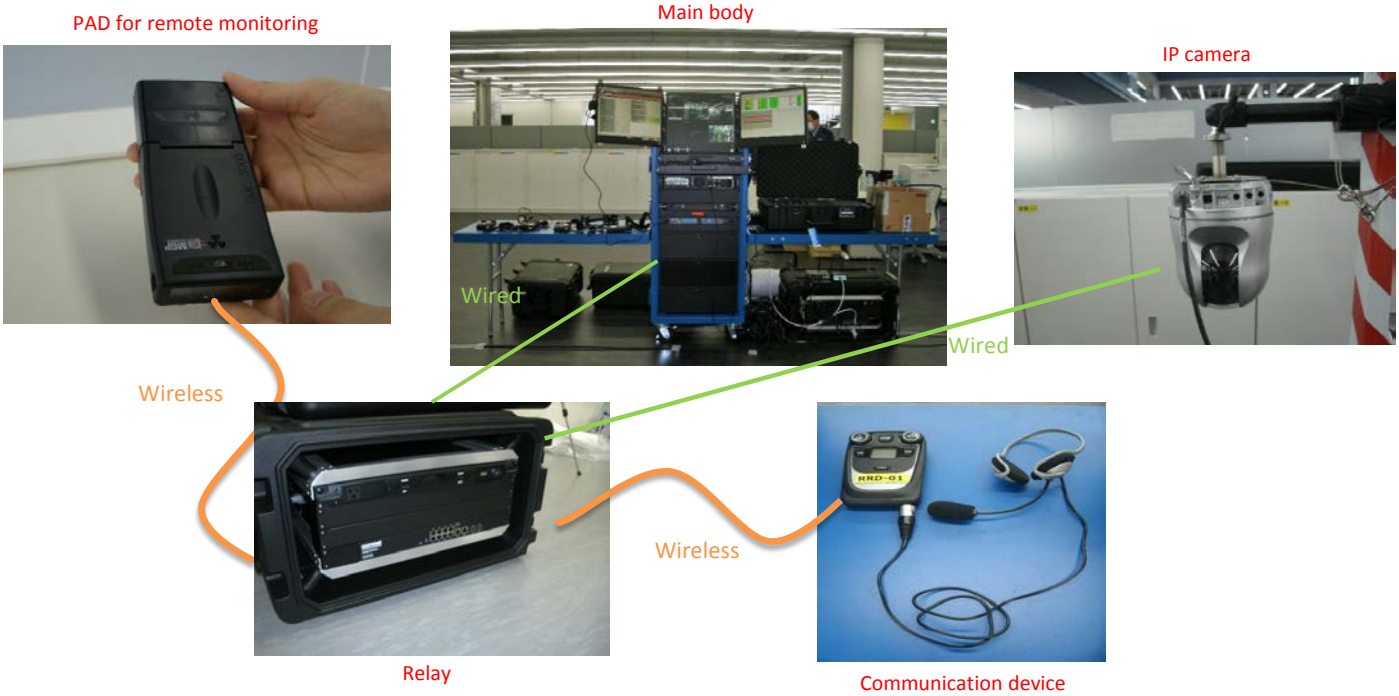
Good Practice Description

Before Implementation
The radiation exposure dose reduction requires an engineering approach and then management measures; however, no management tools were actively adopted.

Implementation Details
The remote monitoring system made in the U.S. has been adopted and it enabled the primary contractor to manage and monitor the workers more smoothly and efficiently, thus realizing radiation exposure dose reduction.

■ Includes an IP camera, headset, and PAD for remote monitoring

When stored: 600 mm (length and width) x 1300 mm (height)
When unfolded: 1300 to 3000 mm (width) x 1600 mm (height)



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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-02-02

Title	Adopting the remote monitoring system
Work location	Areas with a high radiation exposure dose rate such as reactor buildings
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Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
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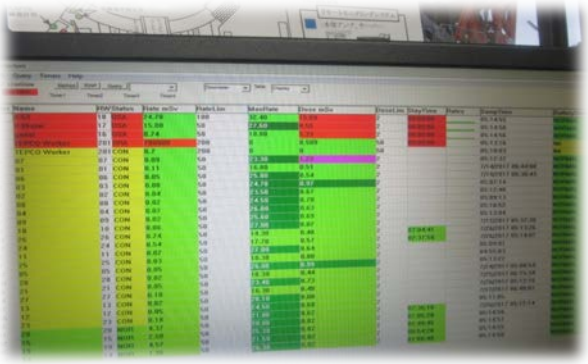
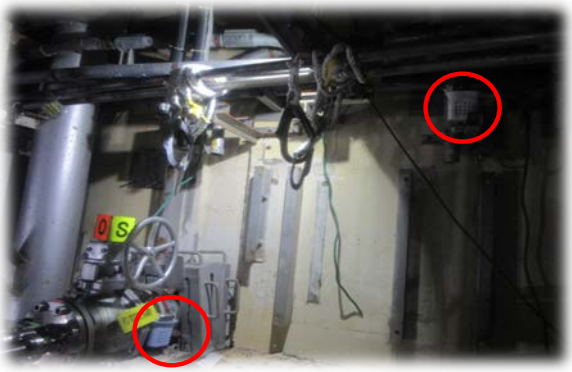
Implementation Details	The remote monitoring system made in the U.S. has been adopted and it enabled the primary contractor to manage and monitor the workers more smoothly and efficiently, thus realizing radiation exposure dose reduction.

State on the site (photos)

Control room



Communication screen



X53 penetration for environment measurement

IP camera images

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-02-03

Title	Configuring the remote monitoring system
Work location	1F of Unit 3 reactor building
Overview	The remote monitoring system has been used to monitor workers' movements and radiation exposure condition.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	119
		Person time (person-days)	--	--

Good Practice Description

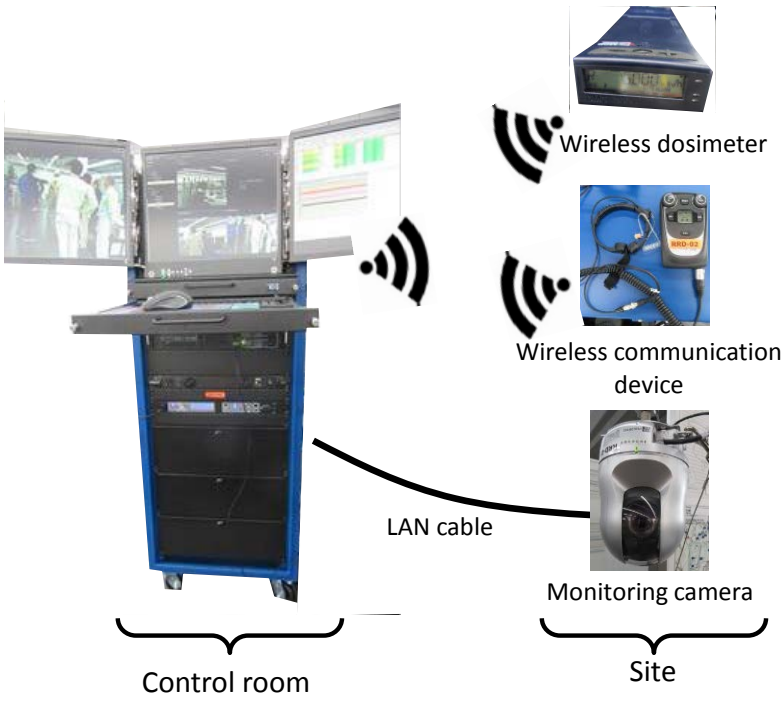
Before Implementation

It was difficult to see the workers' working states and radiation exposure doses at the site in real-time.

Implementation Details

The integrated system including a wireless dosimeter, wireless communication device, and monitoring camera has enabled the monitoring of the work and workers in real-time, thus reducing the radiation exposure of the workers, radiation control administrator, and management staff.

The integrated system including a wireless dosimeter, wireless communication device, and monitoring camera reduces the radiation exposure of the workers, radiation control administrator, and management staff.



Monitoring of radiation exposure dose in real-time

- The total exposure radiation dose of workers
- The estimated exposure radiation dose rate in the work area

Smooth communication

- Voice communication between the control room and the site

The radiation control administrator can wait in the area with a low radiation exposure dose rate.

- Workers who exited the area are monitored by the camera, so the radiation control administrator can conduct surveys at the proper time.

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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category	
Inside reactor building	RB (circled)	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 (circled)	Preventing spread of contamination
			7	Other

No.	29-03

Title	Preventing contamination of insertion apparatus when pulling it out of the PCV
Work location	1F of Units 2 and 3 reactor buildings
Overview	The contamination isolation method has been applied when pulling the insertion apparatus from the PCV to eliminate the need for decontamination and contamination inspection.

Assessment (qualitative/ quantitative) (quantitative circled)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	77
		Person time (person-days)	--	--

Good Practice Description

Before Implementation
The PCV contains alpha nuclides and is highly contaminated, and when the apparatus was inserted to investigate the inside of the PCV, there was a serious risk of radiation exposure during removal and decontamination when the apparatus was being pulled out.

Implementation Details
The contamination isolation method (see below) has enabled removal of the apparatus without the risk of the spread of contamination, thus realizing a significant reduction in decontamination time.

The contamination isolation method that uses the curing tube is used when pulling out the apparatus inserted into the PCV to reduce the radiation exposure caused during the contamination measurement, wiping decontamination, and curing.

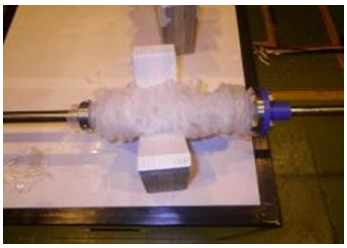

Photo of the curing tube

Curing tube installation

Insertion

Removal

Effects of contamination isolation method

- No bodily contamination, spread of contamination, and dust
- Reduces radiation exposure during the contamination concentration measurement, wiping decontamination, and curing.

Cited from “Unit 3 Reactor: How to Reduce Exposure Dose during Internal Investigation of Reactor Containment Vessel Removal and Installation of Fixed Thermometer” by TEPCO

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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-04-01

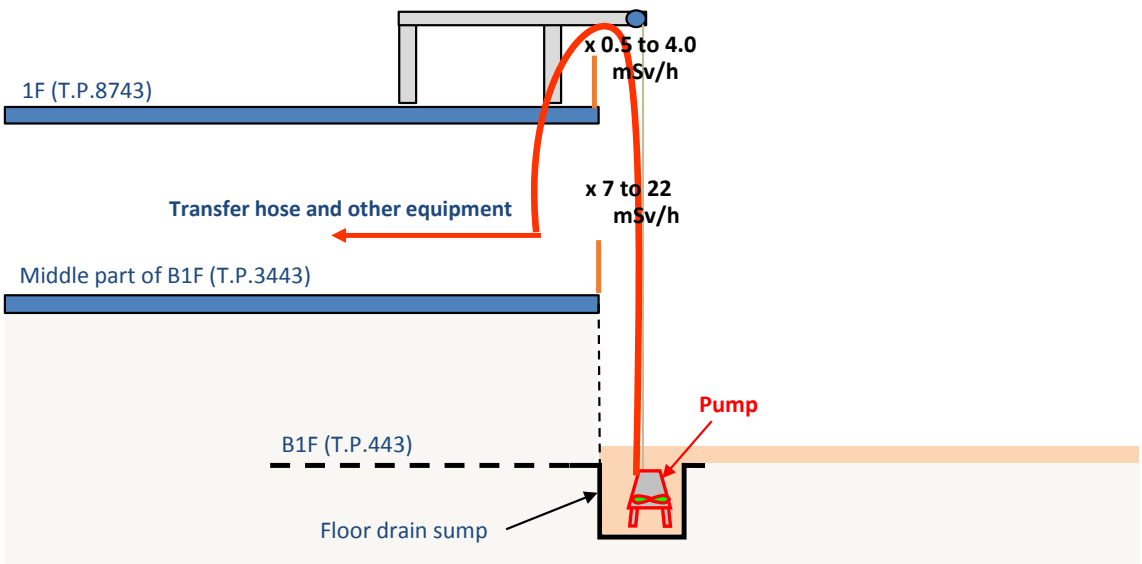
Title	Changing the work place to an area with a low radiation exposure dose rate
Work location	1F of Unit 1 turbine building
Overview	A submersible pump was carried in from 1F where the radiation exposure dose rate was low, but not from the middle part of B1F where the radiation exposure dose rate was high.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	7 to 22	0.5 to 4.0
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The periphery of the floor drain sump had a high radiation exposure dose rate when the workers carried in the submersible pump to B1F of the turbine building.
Implementation Details	The workers carried in the pump to B1F of the turbine building from 1F. The pump had less effect on the heater drain piping.

■ Work done by remote control from the area with a low radiation exposure dose rate

The pump was also carried in from 1F. The pump had less effect on the heater drain piping.



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Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
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
				7	Other

No.	29-04-02

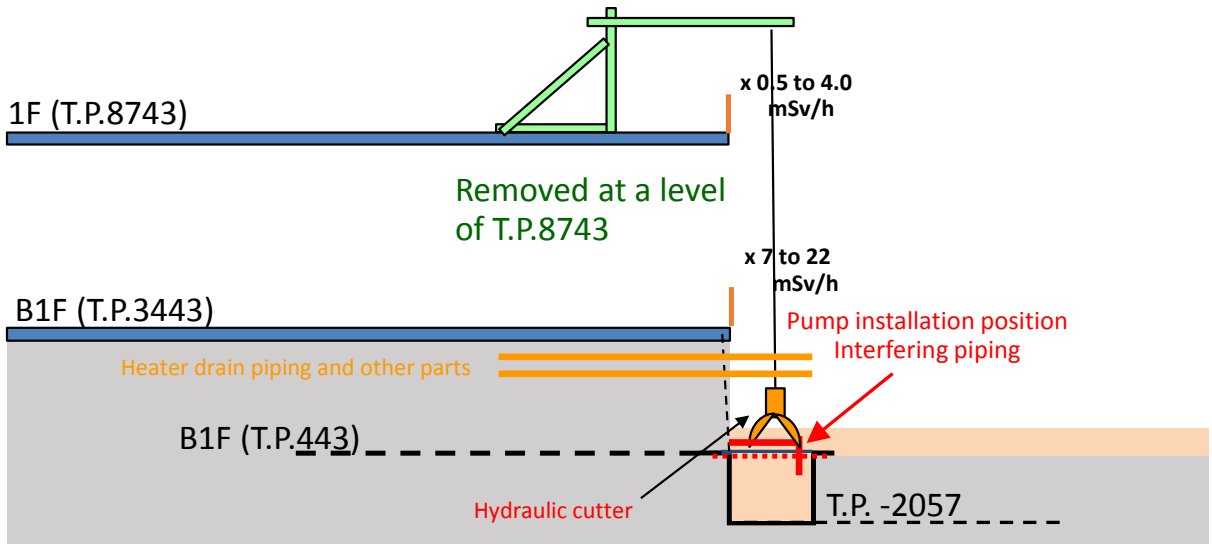
Title	Changing the work place to an area with a low radiation exposure dose rate
Work location	1F of Unit 1 turbine building
Overview	The interfering piping was cut off from 1F, where the radiation exposure dose rate was low, but not from B1F, where the radiation exposure dose rate was high.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	7 to 22	0.5 to 4.0
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The periphery of the floor drain sump (work area in B1F) had a high radiation exposure dose rate when the workers cut the interfering piping from B1F.
Implementation Details	Remote control was done about 10 m away to cut the piping from 1F where the radiation exposure dose rate was comparatively low.

■ Work done by remote control from the area with a low radiation exposure dose rate

The jigs for cutting the interfering piping (such as hydraulic cutters) were prepared, and the piping was cut from 1F, which had less effect on the heater drain piping.



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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-05-01

Title	Shielding heater drain piping and other parts
Work location	The B1F heater room of Unit 1 turbine building
Overview	The heater drain piping and the trench top in the B1F heater room have been shielded with shielding sheets (1,660 in total).

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	5.6	1.6
		Person time (person-days)	--	--

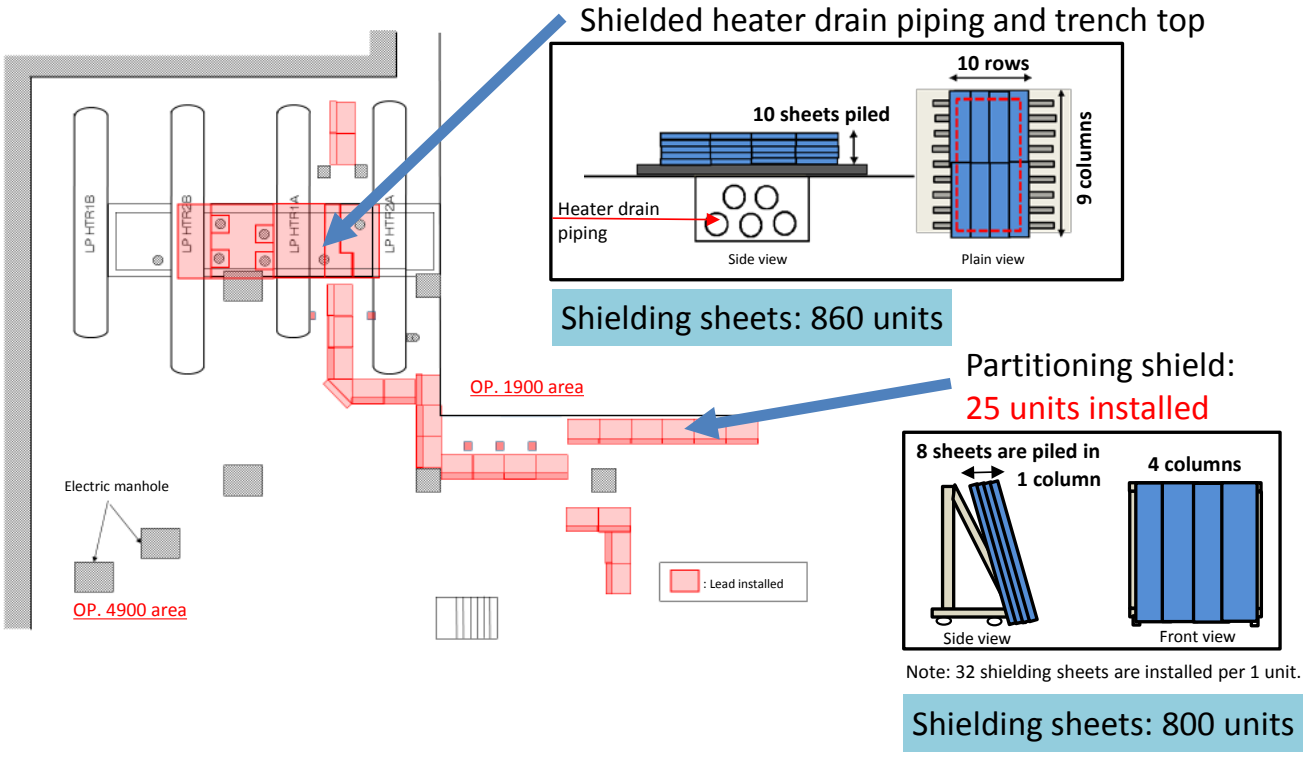
Good Practice Description

Before Implementation

The heater drain piping and the trench top had a high radiation exposure dose rate, and the areas needed to be shielded.

Implementation Details

A total of 1,660 shielding sheets were installed to the above areas to reduce the radiation exposure dose rate.



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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-05-02

Title	Shielding heater drain piping and other parts
Work location	The B1F heater room of Unit 1 turbine building
Overview	The heater drain piping and other parts have been shielded because the piping connected to the condenser was the radiation source.

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

Good Practice Description

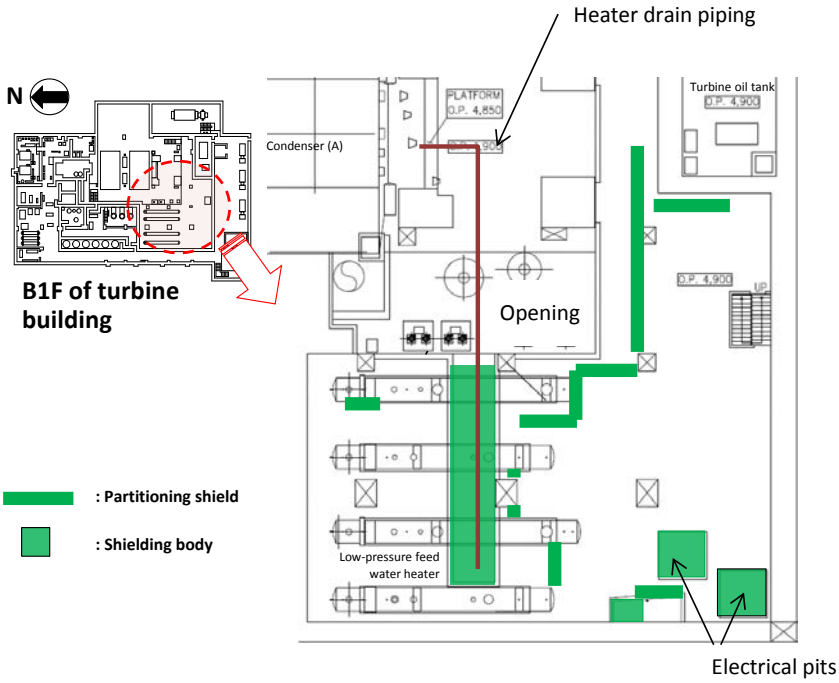
Before Implementation: The heater drain piping was the radiation source, and the work done around it had a higher risk of radiation exposure.

Implementation Details: The radiation exposure has been reduced by shielding the piping and other parts with lead mats.

■ Reducing the radiation exposure dose in the unit installation area in the basement

Shielding the heater drain piping and other parts

The heater drain piping, electrical pit, and opening were shielded.



The shielding in the diagram includes installation by several companies.

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-06

Title	Shielding the accessible area of the upper part of the condenser
Work location	Around the condenser neck heater in 1F of Unit 1 turbine building
Overview	The condenser surface has been shielded to reduce the radiation exposure at the upper part of the condenser.

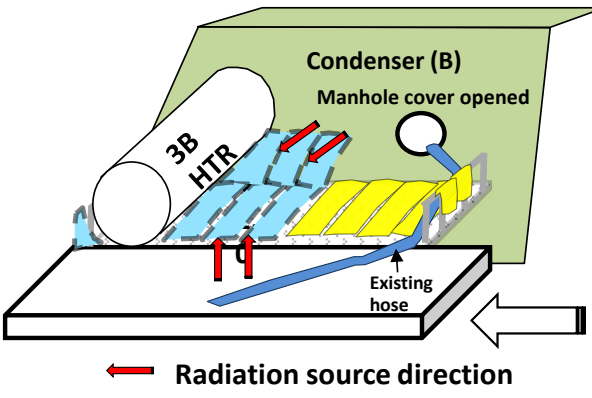
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The inside of the condenser had a high radiation exposure dose rate, and thus the upper part of it also had a high radiation exposure dose rate.
Implementation Details	The condenser surface has been shielded to reduce the radiation exposure at the upper part of the condenser when the workers perform drilling and carry in a pump.

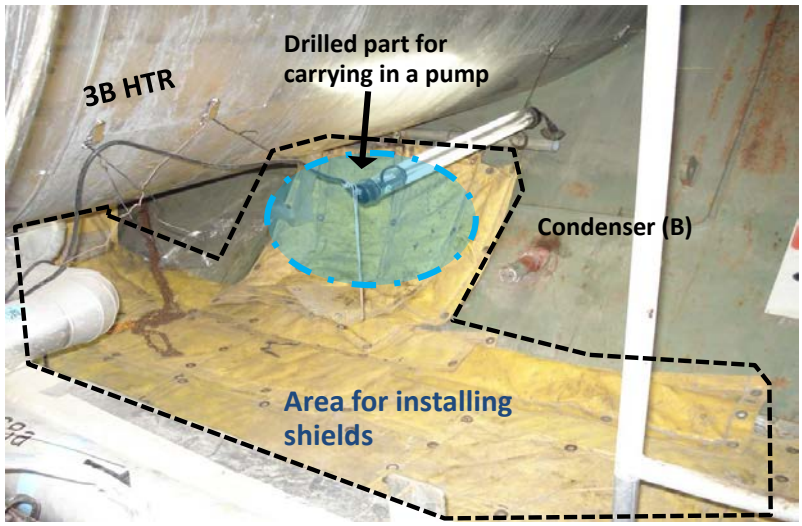
■ Reducing the radiation exposure dose in the unit installation area in the basement

Water with a high radiation exposure dose rate was stored in the condenser

The area for carrying in the pump was shielded to reduce the radiation exposure dose rate.



Condenser B (shielding state)



Condenser B (shielding state)

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-07

Title	Shielding the transfer lines of water stored in the condenser
Work location	The 1F heater room of Unit 1 turbine building
Overview	The transfer lines were shielded for transferring water stored in the condenser.

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

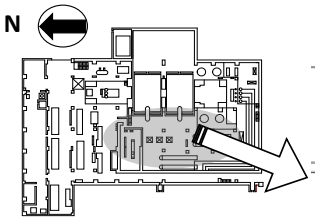
Good Practice Description

Before Implementation: The inside of the condenser had a high radiation exposure dose rate, and thus draining and transferring the diluted water also had the risk of a high radiation exposure dose rate.

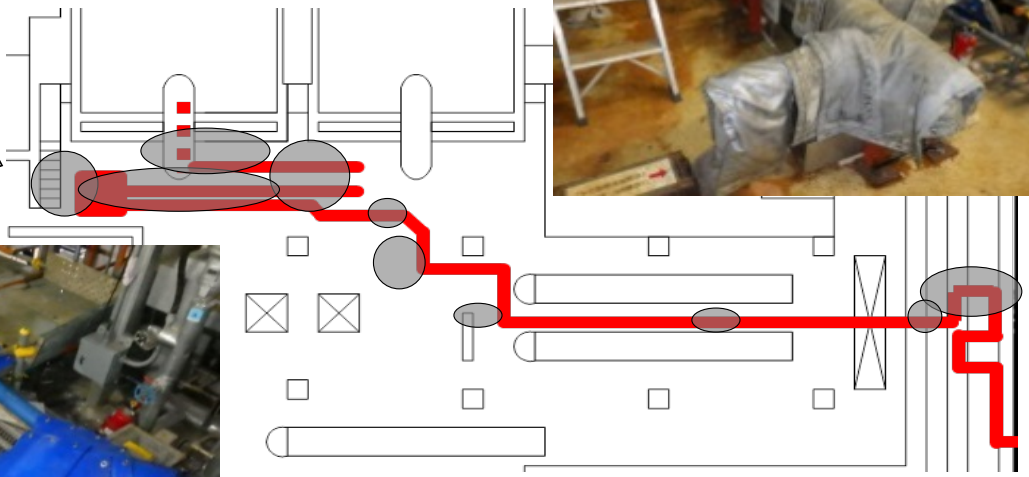
Implementation Details: The radiation exposure during transfer has been reduced by shielding the transfer lines with lead mats.

Water with a high radiation exposure dose rate was stored in the condenser

The radiation exposure during transfer has been reduced by installing shields to the transfer lines of the water stored in the condenser.



1F of Unit 1 turbine building



Shielding state (transfer lines of water stored in the condenser)

Area for installing shields

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Good Practices in Radiation Exposure Dose Reduction Measures

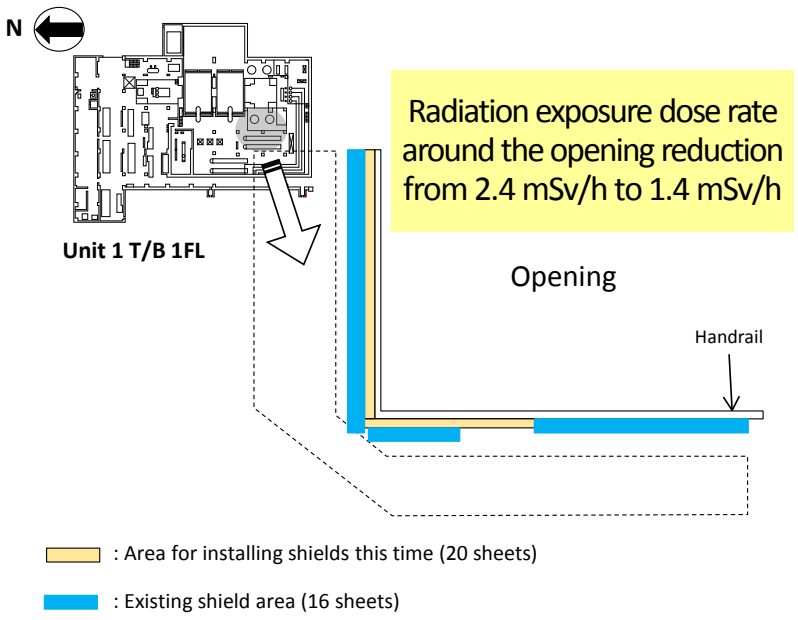
Location			Category	
Inside reactor building	RB	TB	1	Time
Inside turbine building	TB		2	Distance
R ZONE	R		3	Shielding
Y ZONE	Y		4	Removing radiation source
G ZONE	G		5	Remote-control, robot operation
Other ( )	Z		6	Preventing spread of contamination
			7	Other

No.	29-08
Title	Shielding the opening around the condenser
Work location	The 1F opening side of Unit 1 turbine building
Overview	Shields were installed on the handrail of the opening of the heater room, which is the remote control area.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	2.4	1.4
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The opening side of the heater room, which is the work area, had a comparatively high radiation exposure dose rate.
Implementation Details	Additional shielding mats were installed on the handrail of the opening to reduce the radiation exposure dose rate.

The remote control area on 1F was also shielded to further reduce the radiation exposure dose rate.



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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-09-01
Title	Installing pre-assembled partitioning shields
Work location	B1F heater room of Unit 1 turbine building
Overview	The heater drain piping and the trench top have been shielded with shielding sheets (1,660 in total). The pre-assembled partitioning shields were used to reduce the installation time.

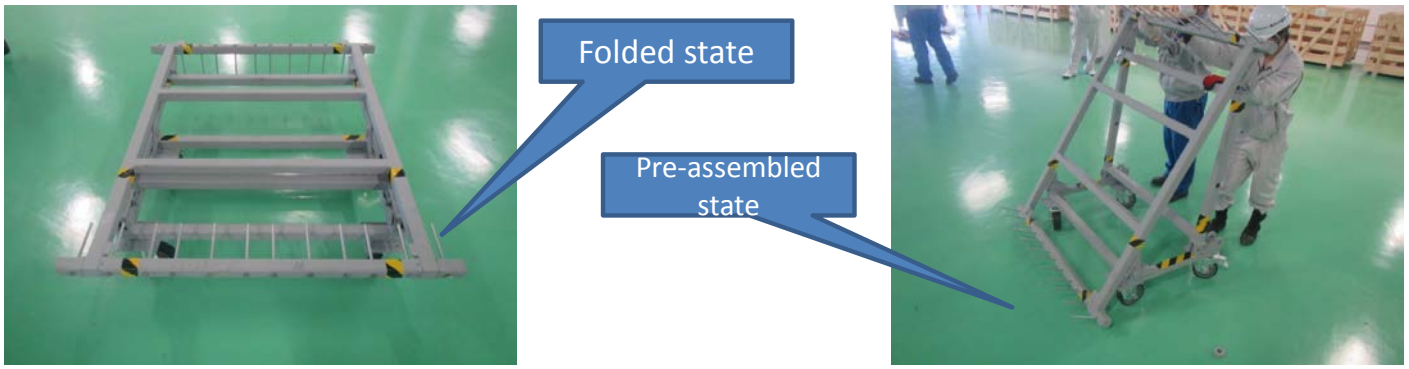
Assessment (qualitative/ quantitative) (○)	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	2.8	0.11
		Person time (person-days)	--	--

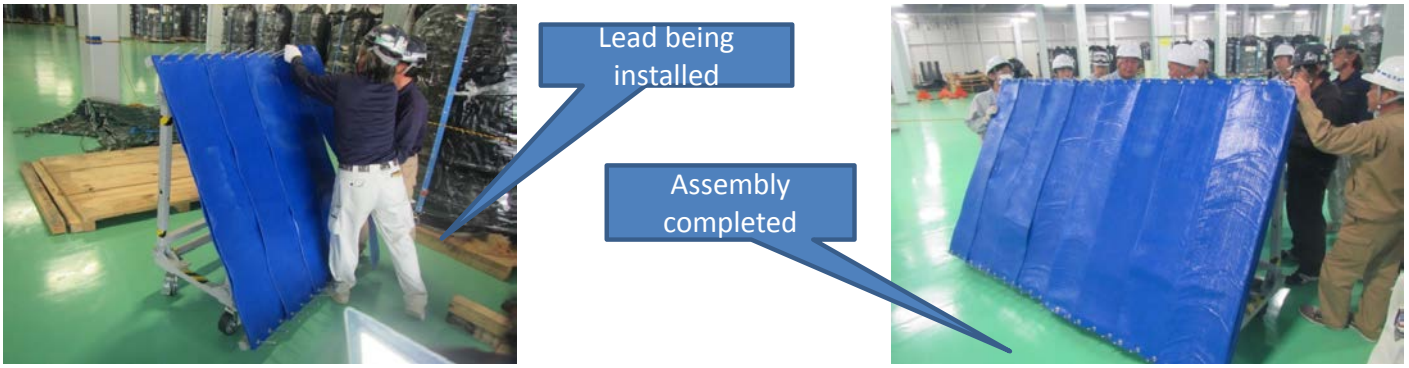
Good Practice Description

Before Implementation: The heater drain piping and the trench top had a high radiation exposure dose rate, and the areas needed to be shielded.

Implementation Details: The pre-assembled partitioning shields were used to reduce the installation time.

Installation of pre-assembled partitioning shields (image photos)





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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-09-02
Title	Installing pre-assembled partitioning shields
Work location	B1F heater room of Unit 1 turbine building
Overview	The heater drain piping and the trench top have been shielded with the shielding sheets (1,660 in total). The pre-assembled partitioning shields were used to reduce the installation time.

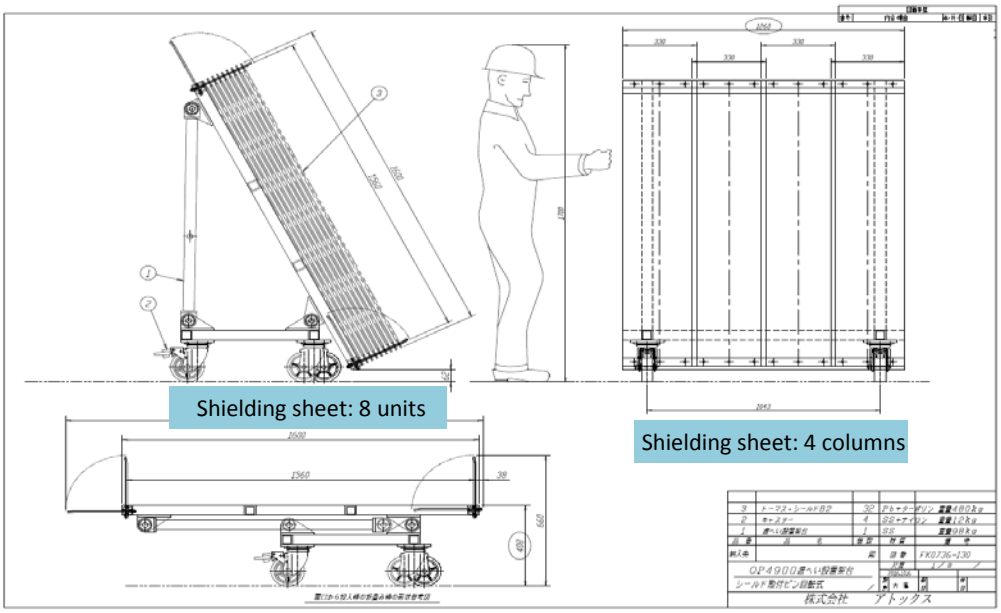
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate (mSv/h)	2.8	0.11
		Person time (person-days)	--	--

Good Practice Description

Before Implementation: The heater drain piping and the trench top had a high radiation exposure dose rate, and the areas needed to be shielded.

Implementation Details: The pre-assembled partitioning shields were used to reduce the installation time.

Overview of assembly partitioning shields



Shielding sheet

- Lead thickness: 3 mm/sheet
- Weight: about 16 kg/sheet

Assembly partitioning sheet

- Lead thickness: 24 mm
- Lead weight: about 512 kg/unit
- Frame weight: about 100 kg/unit
- Assembly time: about 10 min/unit
- Movable: with casters
- Separable: into 3 parts

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Location			Category		
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
				7	Other

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-10-01

Title	Removing accumulated sludge
Work location	B1F heater room of Unit 1 turbine building
Overview	The radioactive sludge accumulated on the heater room floor was removed.

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

Good Practice Description

Before Implementation The heater room had a high radiation exposure dose rate because of the influence of the sludge widely accumulated on the floor.

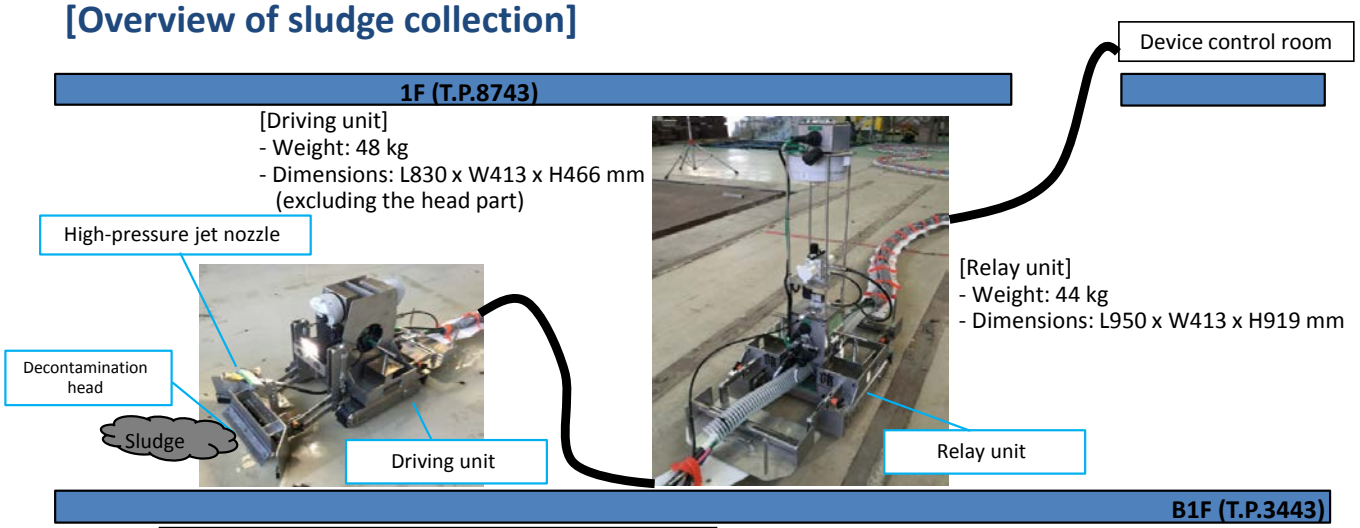
Implementation Details The accumulated sludge was removed by a remotely operated device to reduce the radiation exposure rate in the heater room.

■ Reducing the radiation exposure dose in the unit installation area in the basement

Removing sludge on floor (decontamination)

The sludge on the floor was removed with a small remotely operated device.

[Overview of sludge collection]



[Driving unit]
- Collects the sludge on the floor.
- The sludge is transported in a narrow area using high-pressure water, and wall equipment is decontaminated by spraying water.
- The sludge is moisturized by spraying water over a wide angle.

[Relay unit]
- Monitors the driving unit, and pulls the cable.

From the website of TEPCO

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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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-10-02

Title	Removing accumulated sludge
Work location	B1F heater room of Unit 1 turbine building
Overview	The radioactive sludge accumulated on the heater room floor was removed.

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

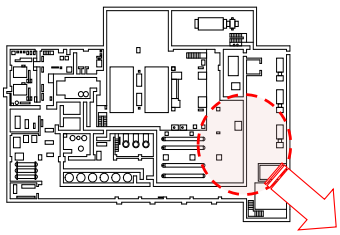
Good Practice Description	
Before Implementation	The heater room had a high radiation exposure dose rate because of the influence of the sludge widely accumulated on the floor.
Implementation Details	After removing the sludge by a remotely operated device, workers wiped the heater chamber floor to further reduce the radiation exposure dose rate.

■ Reducing the radiation exposure dose in the unit installation area in the basement

Removing sludge on floor (decontamination)

N

T/B B1F



After removing the sludge by a remote device, workers wiped the heater room floor.

Being wiped

After being wiped

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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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-11

Title	Diluting the water with a high radiation exposure dose rate that was stored in the condenser.
Work location	Around the condenser neck heater in B1F of Unit 1 turbine building
Overview	After being diluted, the water stored in the condenser was transferred and drained to reduce radiation exposure.

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

Good Practice Description

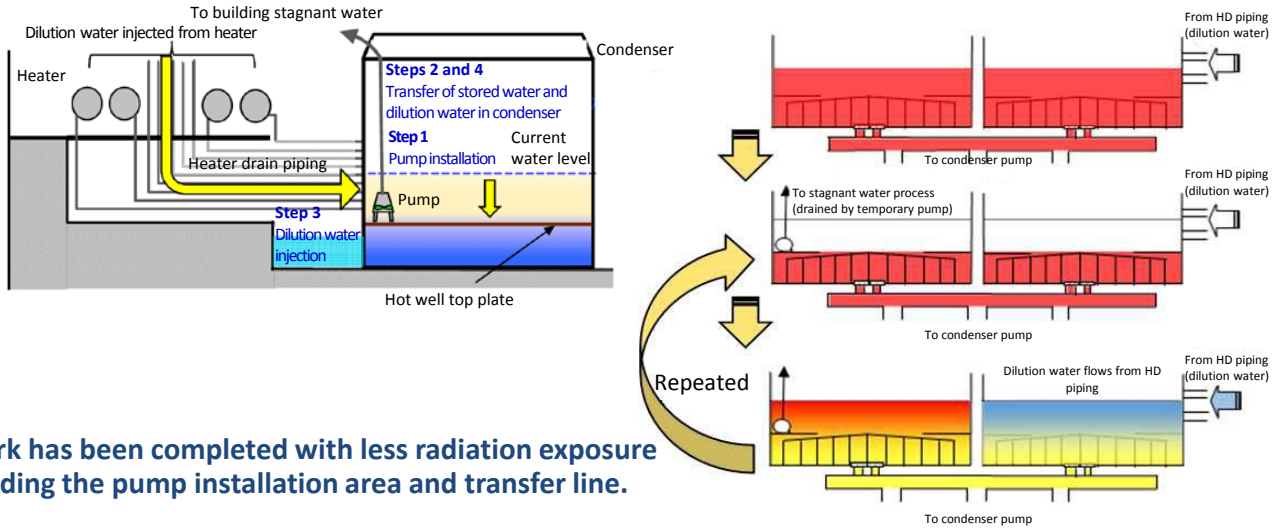
Before Implementation The water stored in the condenser had a high radiation exposure dose rate, and therefore, had a higher risk of radiation exposure when being transferred.

Implementation Details The work was conducted after diluting the water stored in the condenser to a radioactive concentration of about 1/30 of the original value.

■ Reducing the radiation exposure dose in the unit installation area in the basement

Water with a high radiation exposure dose rate was stored in the condenser

Dilution water was injected into the water stored in the condenser to reduce its radioactivity concentration to about 1/30 of the original value, and thus reduce the radiation exposure dose rate during transfer.



The work has been completed with less radiation exposure by shielding the pump installation area and transfer line.

From the website of TEPCO

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Good Practices 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.	29-12

Title	Setting and indicating the access route
Work location	All of 1F of Unit 1 turbine building
Overview	The route for entering and exiting the work area was set beforehand so the workers can pass through the area with a low radiation exposure dose rate. Signs were put on the route to prevent entering the area with a high radiation exposure dose rate.

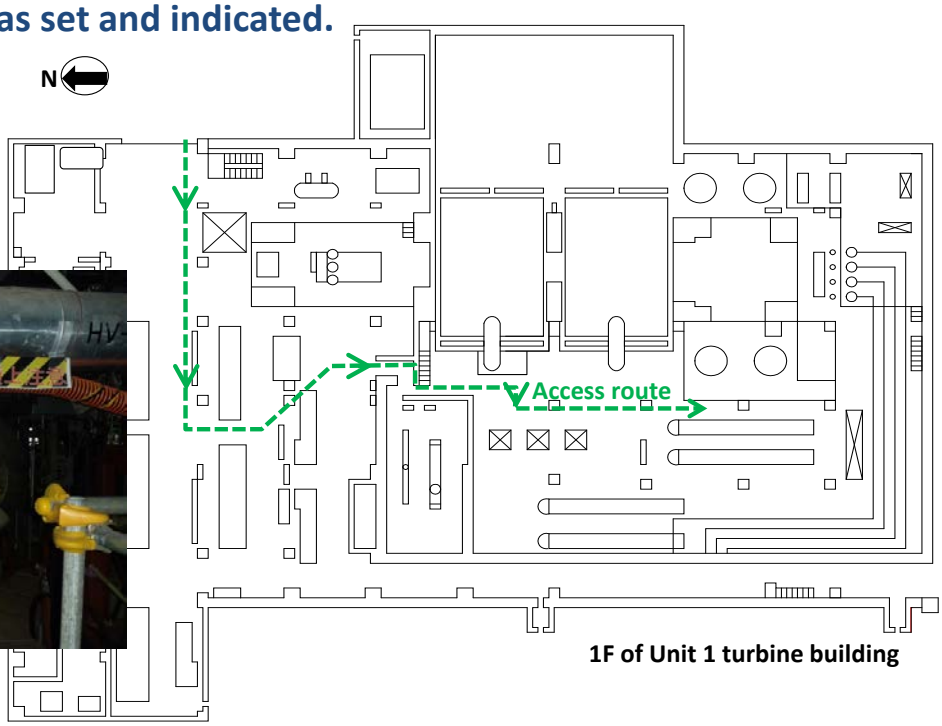
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The quickest route to the work area included the area with a high radiation exposure dose rate and had a higher risk of radiation exposure.
Implementation Details	The route with a low radiation exposure dose rate was set beforehand and signs were put on the route to prevent entering the area with a high radiation exposure dose rate.

■ Setting and indicating the access route with a low radiation exposure dose rate

The access route to the condenser room basement with a low radiation exposure dose rate was set and indicated.

Sign of access route



1F of Unit 1 turbine building

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-13

Title	Setting lifting facilities in areas with a low radiation exposure dose rate
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	The installation of new scaffoldings was conducted before beginning the application of waterproof coating to the rooftops of the turbine buildings and visual control of exposure radiation dose rate was implemented during the work.

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

Good Practice Description

Before Implementation
(1) The existing scaffoldings were in the area with a high radiation exposure dose rate.
(2) When removing rubble, displaying the radiation exposure dose was difficult because the work was conducted outside.

Implementation Details
(1) New scaffoldings were installed in the areas with a low radiation exposure dose rate
(2) The radiation exposure dose was displayed on the rooftop floor in different colors.

■ Installation of lifting facilities

■ Indication of radiation exposure dose rates

Red: above 2.5 mSv/h

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-14

Title	Setting traffic lines and waiting areas at places with low radiation exposure doses
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	The traffic lines and waiting areas with low radiation exposure doses were set when work was done to apply waterproof coating to the rooftops of the turbine buildings.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0 (Unit 2)	Relative value of 0.46 (Unit 2)
		Person time (person-days)	--	--

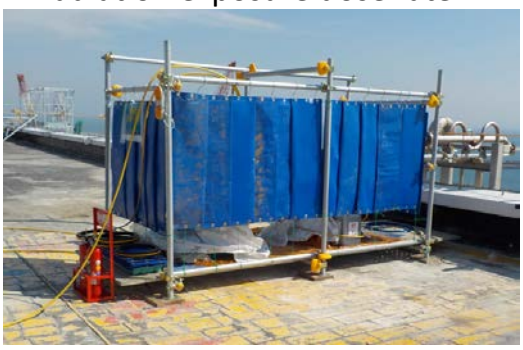
Good Practice Description

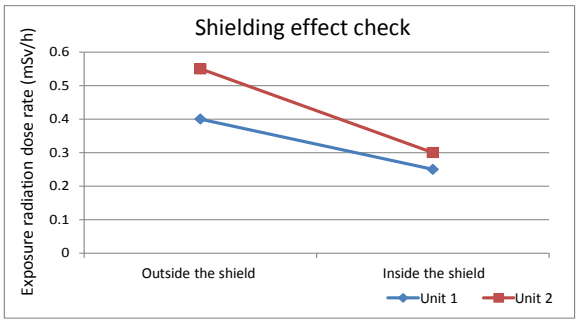
Before Implementation: The radiation exposure dose on the rooftop fluctuates widely, and therefore, there was a risk of serious radiation exposure.

Implementation Details: Regarding movement to the work area, the areas with a low radiation exposure dose rate were specified, the traffic lines were indicated, and the waiting areas with a low radiation exposure dose rate were set.

■ Setting the transfer line at a place with a low radiation exposure dose rate

■ Setting a waiting area with a low radiation exposure dose rate





Unit 1: reduction effect of 31%

Unit 2: reduction effect of 54%

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-15

Title	Shielding the periphery of Unit 3 reactor building
Work location	The west yard of Unit 3 reactor building
Overview	For the internal investigation of the Unit 3 PCV, the site control office has been set up in the west yard of the reactor building. The area is affected by radiation from the reactor building, and therefore, was shielded with lead partitioning shields.

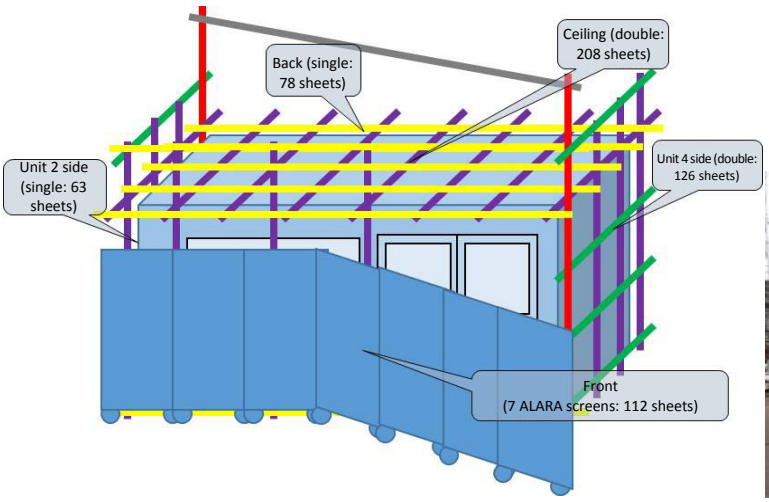
Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0	Relative value of 0.3 (228)
		Person time (person-days)	--	--

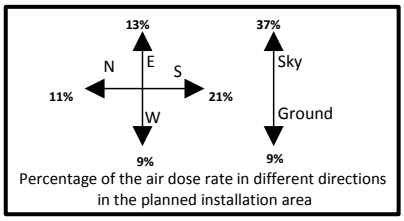
Good Practice Description

Before Implementation
The site control office required shielding because the reactor building was the radiation source.

Implementation Details
The lead mats and partitioning shields were installed on the ceiling and side surfaces so as to cover the site control office.

Lead plate mats were installed around the temporary control office to reduce the air dose rate inside the control office.





Percentage of the air dose rate in different directions in the planned installation area


Installation of site control office (at 1st entry)

<u>The air dose rate inside the control office was reduced by 70% compared to before shielding installation.</u>

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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-16

Title	Shielding for radioactive substances from the upper part of Unit 3 turbine building
Work location	On the seaside of Unit 3 turbine building
Overview	The work area and ceiling parts were shielded with concrete retaining walls and lead plates to shield against radiation (gamma rays) from the turbine buildings.

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

Good Practice Description	
Before Implementation	Radiation is emitted not just from the ground but also from the upper part of the turbine building; therefore, the work area also needed upper shielding.
Implementation Details	Concrete retaining walls and lead plates were used to install the shielding walls and to shield the roof. The workers wore shielding vests.

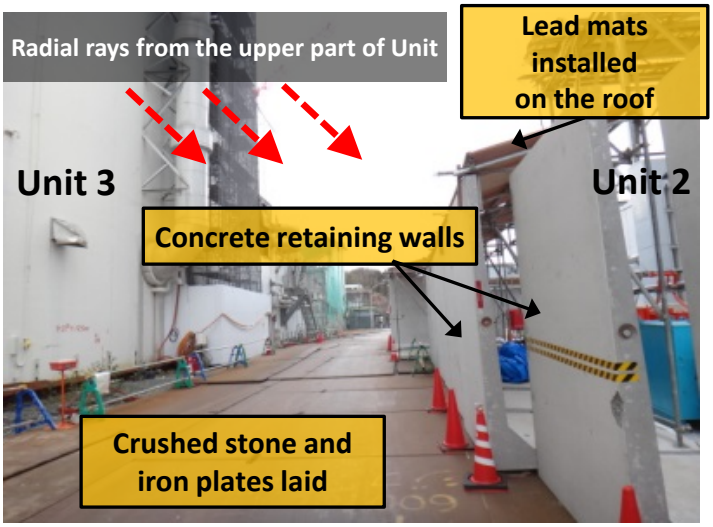
(1) How to shield against radiation

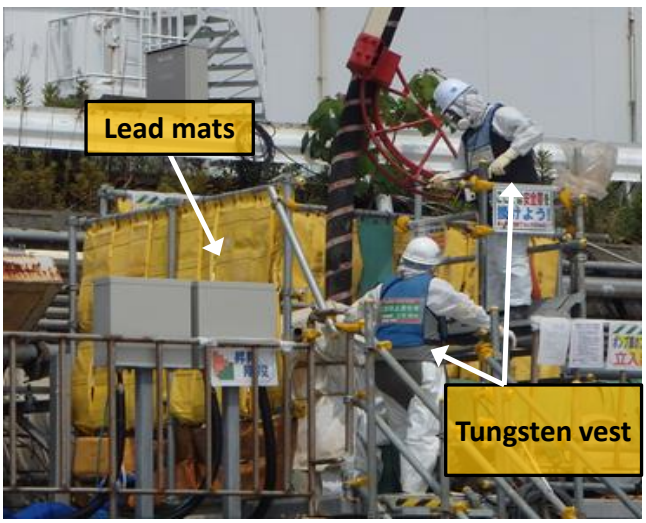
- Ground => crushed stone, iron plates

- Air => concrete retaining wall, lead mats

(2) Isolation from the position with a high radiation exposure dose rate

(3) Tungsten vest (shield)





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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-17

Title	Shielding for beta rays inside the flange tank
Work location	Flange tank disassembly area in the yard
Overview	When the workers entered the tank, the bottom plate was shielded with rubber mats and the side plate was shielded with concrete panels and aluminum plates.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose rate inside the tank (mSv/h)	89.4	2.4
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

The tank needed shielding because there was a high beta dose rate inside.

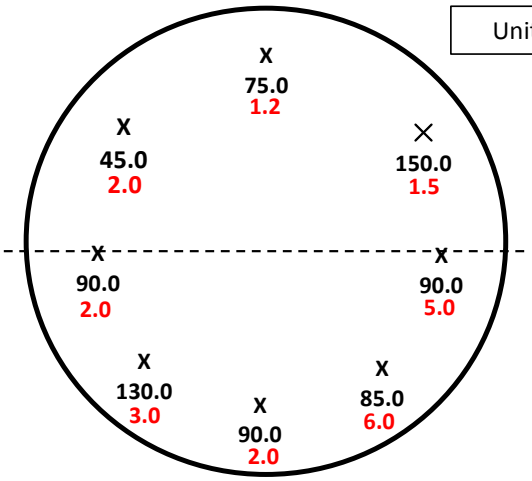
Implementation Details

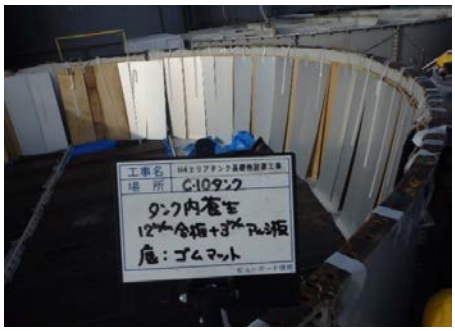
When the workers entered the tank, the bottom plate was shielded with rubber mats and the side plate was shielded with concrete panels and aluminum plates to shield against the beta rays inside the tank.

Measurement result of dose rate inside C10 tank
(measurement area: 50 cm from the side plate, 1.2 m from the floor)
Black: before implementation
Red: after implementation

Measure: installation of shielding materials
- Install rubber mats on the bottom of the tank.
- Install concrete panels and aluminum plates on the side plate of the tank

Unit: mSv/h





Reduction effect (average value of dose equivalent rates)
Before implementation: 89.4 mSv/h
After implementation: 2.4 mSv/h (reduced by 97%)

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-18

Title	Adopting shielding trolleys
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	The shielding trolleys were adopted during work to apply waterproof coating to the rooftops of the turbine buildings.

Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0	Relative value of 0.46
		Person time (person-days)	--	--

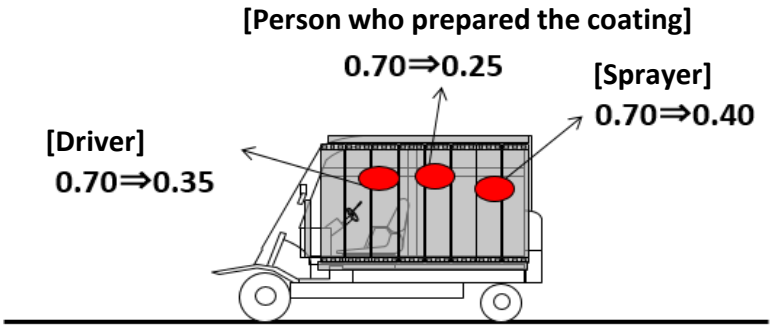
Good Practice Description

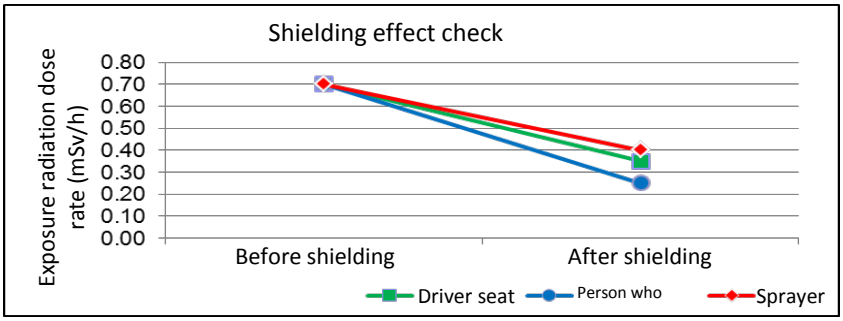
Before Implementation

The reactor building adjacent to the rooftop floor was still the radiation source even after rubble removal.

Implementation Details

Trolleys with shields were adopted and workers did the coating work from inside the trolleys.





Reduction effect of 54%

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Location			Category		
Inside reactor building	RB	R	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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	29-19-01

Title	Removing rubble before applying waterproof coating
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	The rubble was removed before applying waterproof coating to the rooftops of the turbine buildings.

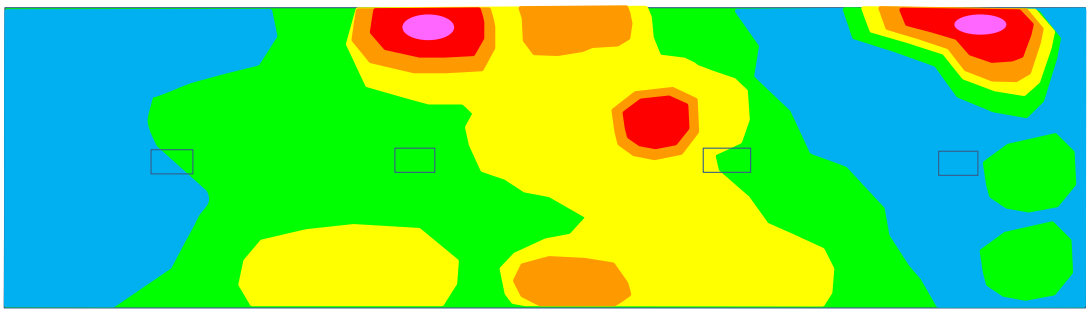
Assessment (qualitative/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	--
		Person time (person-days)	--	--

Good Practice Description	
Before Implementation	The turbine building rooftop were scattered with rubble and had a high radiation exposure dose rate.
Implementation Details	Other work was performed after removing the rubble and reducing the overall radiation exposure dose rate.

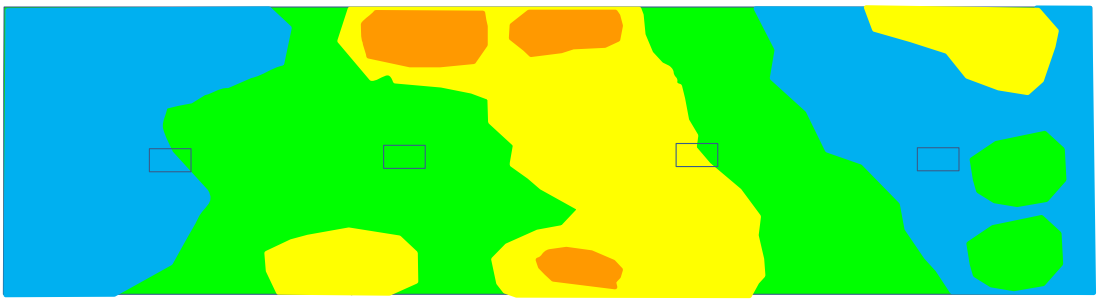
The exposure radiation dose rate in the area before and after the rubble removal

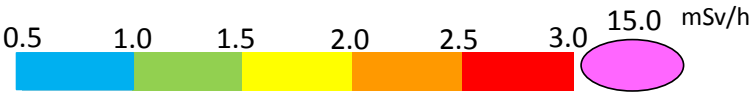
Unit 1 T/B rooftop

Before rubble removal



After rubble removal





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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-19-02

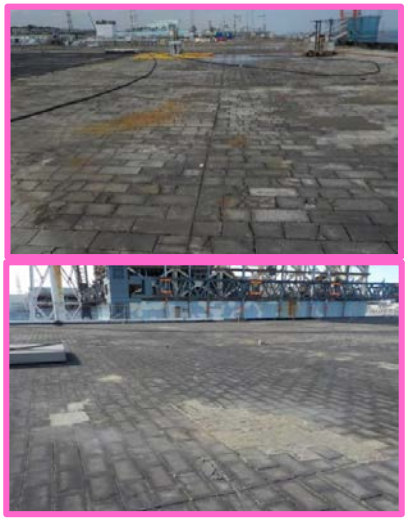
Title	Removing rubble before applying waterproof coating
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	Photos showing progress (before rubble removal → after rubble removal → after applying waterproof coating)

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

Good Practice Description

Before rubble removal

After rubble removal



After applying waterproof coating

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-20

Title	Using a remote sprayer to control spreading of the contamination on the inner surface of the tank
Work location	Flange tank disassembly area in the yard
Overview	The flange tank disassembly work exposes contaminated parts; therefore, a remote sprayer has been developed to control the spread of the contamination and to reduce labor hours.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	42.3 per tank	0 per tank
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

Before starting the tank disassembly work, the inner surface needs to be sprayed with a coating so the contamination spread can be controlled; however, entering the tank presented problems of safety and workload.

Implementation Details

The sprayer has been developed so that workers can spray coating on the inner surface of the tank without entering it.

Overall appearance of device

Installation of spraying device

Spraying state
(water-based epoxy anticorrosive material)

Spray completion

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-21

Title	Contamination management during flange tank disassembly
Work location	Preventing contamination spread and internal exposure when exiting the tank
Overview	An exit area was provided to prevent the contamination spread. The workers' equipment was removed by dedicated radiation control administrators to prevent internal contamination and body contamination of workers while undressing.

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

Good Practice Description

Before Implementation
The inside of the tank is highly contaminated. There was a risk of contamination spread, internal contamination, and body contamination when the workers exit the tank or undress.

Implementation Details
An exit area was provided and the workers' equipment was removed by dedicated radiation control administrators in the exit area to prevent contamination spread, internal contamination, and body contamination.

Equipment exchange place

Equipment check by dedicated radiation control administrator

Anorak removal by dedicated radiation control administrator

Place to keep boots for work site

The following measures have been thoroughly carried out:
(1) Dividing the work area into several zones
(2) Making equipment checks by dedicated radiation control administrators
(3) Making contamination inspections after work

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-22

Title	Reducing workload by developing and using the superfluid concrete material
Work location	On the seaside of Unit 3 turbine building
Overview	The development of the superfluid concrete material has eliminated the need to drill drive holes, resulting in a reduction in work such as backfilling.

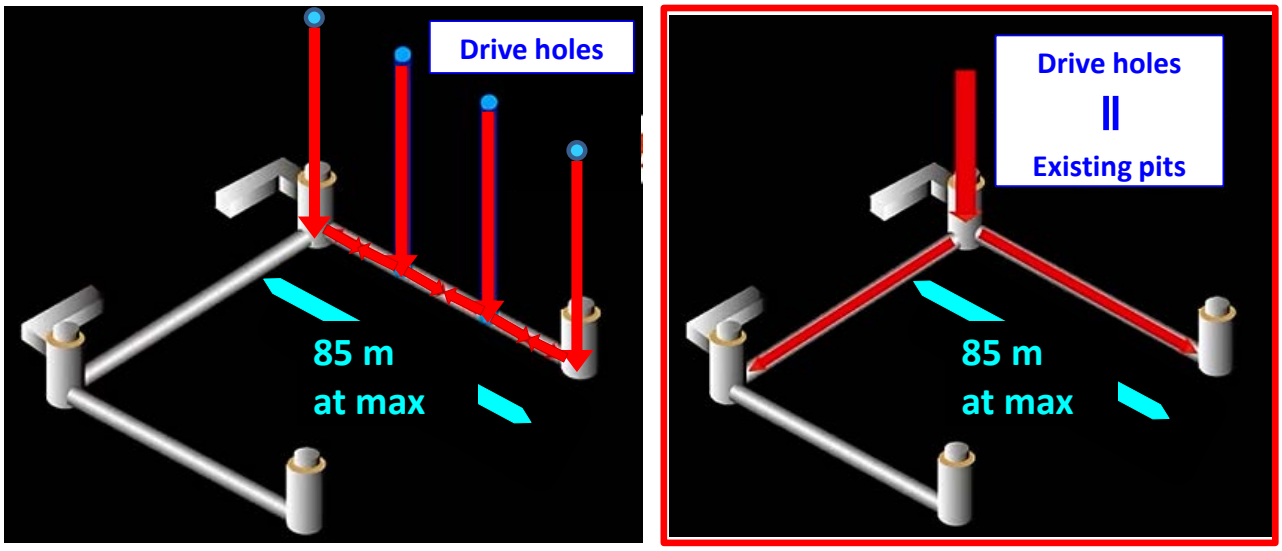
Assessment (~~qualitative~~/ quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0	Relative value of 0.25
		Person time (person-days)	--	--

Good Practice Description

Before Implementation The conventional concrete material had poor fluidity in horizontal parts and required drilling new drive holes (on the left in the diagram below).

Implementation Details The development of the concrete material with high fluidity has eliminated the need to drill new drive holes (on the right in the diagram below).

◆ **Conventional method** → ◆ **Adopted new method**



Only existing pits are used for driving

◆ **Application that utilized the performance of filler for long-distance underwater flow**

- Eliminated the need to drill middle drive holes

No additional work of drilling, driving, height measurement, or backfilling

- Minimum workload

driving from 1 place: reduction in the number of workers and workload

Radiation exposure dose rate: reduced by about 75%

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Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	29-23

Title	Mechanizing waterproof coating
Work location	The rooftops of Units 1 and 2 turbine buildings
Overview	The coating method was mechanized for application of waterproof coating to the rooftops of the turbine buildings.

Assessment (qualitative/ (quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	Relative value of 1.0	Relative value of 0.46
		Person time (person-days)	--	--

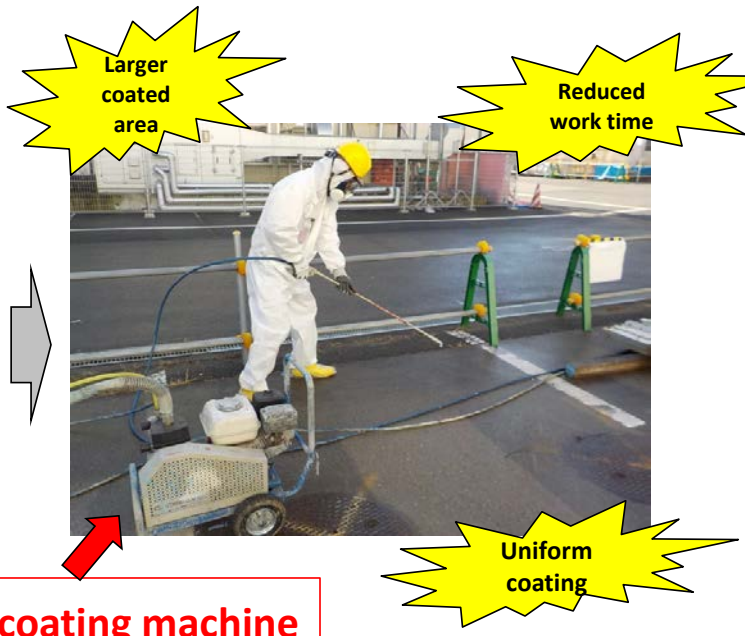
Good Practice Description

Before Implementation

The conventional waterproof coating was conducted by manual labor (using watering cans and rollers).

Implementation Details

The waterproof coating was mechanized. The airless coating machine was used to improve the quality and decrease the work time.



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The L-shaped concrete retaining walls used during the contaminated tank disassembly work and the lead plate shielding partitions

(Material provided by TAISEI CORPORATION)

Good Practices in Radiation Exposure Dose Reduction Measures

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FY2017 Project to Enhance the International Transmission of Radioactivity-Related Information on the Workers at TEPCO Holdings' Fukushima Daiichi Nuclear Power Plant

Assignee: Japan Environment Research Co., Ltd.