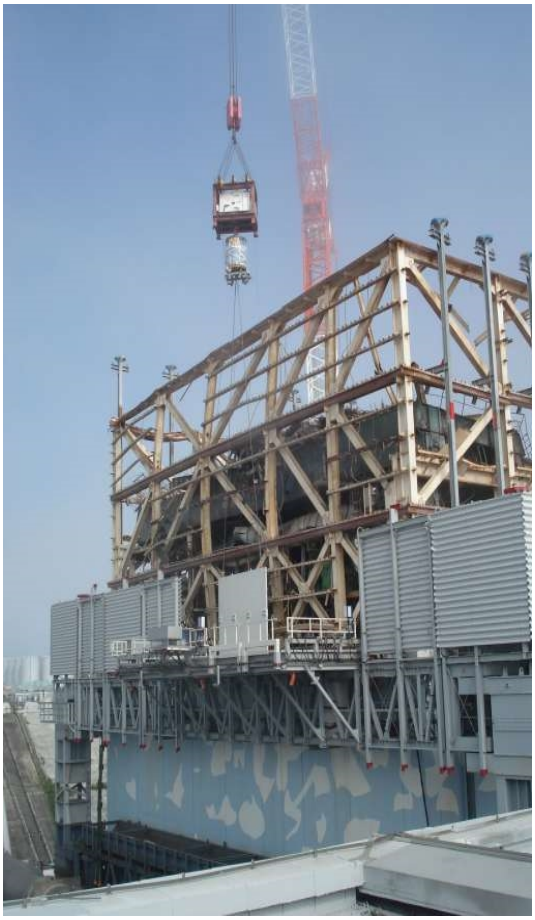
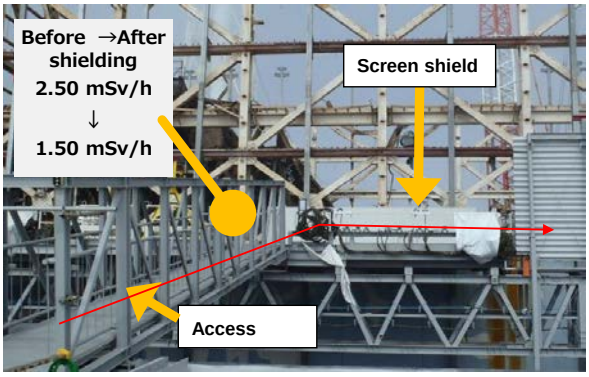
Commissioned by the Ministry of Health, Labour and Welfare
"FY2018 Project to Enhance the Radiation Exposure Dose Reduction Measures for works Relating to the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant〃

Good Practices in Radiation Exposure Dose Reduction Measures



State of the hanging shield for the south work platform



State of the screen shield for the east work platform

Installation status of hanging shields in the installation of work platforms and power supply/communication equipment on the outer circumference of the operating floor of the 1F-1 reactor building

Source: Hitachi-GE Nuclear Energy, Ltd.

Edited by: Japan Environment Research Co., Ltd.

Principles for Radiation Exposure Protection

(1) Reducing external exposure

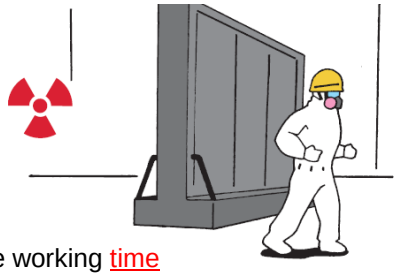
To reduce **external exposure,** it is important to understand the following four principles of radiation exposure protection

Principle 1 Remove radioactive materials

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

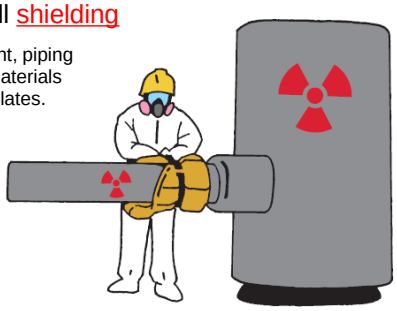
Principle 2 Maintain sufficient distance from radiation

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

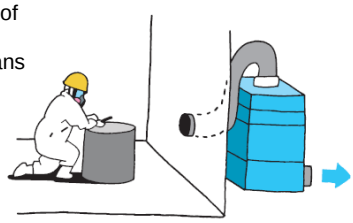
Measures also need to be put in place to prevent radioactive materials from being blown around in the air, as well as to contain (and limit) any contamination and stop it spreading (dispersing).

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

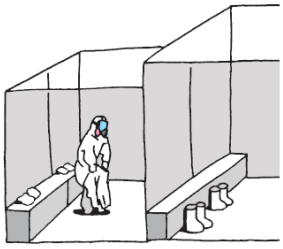


Principle 3 Move to safety

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.



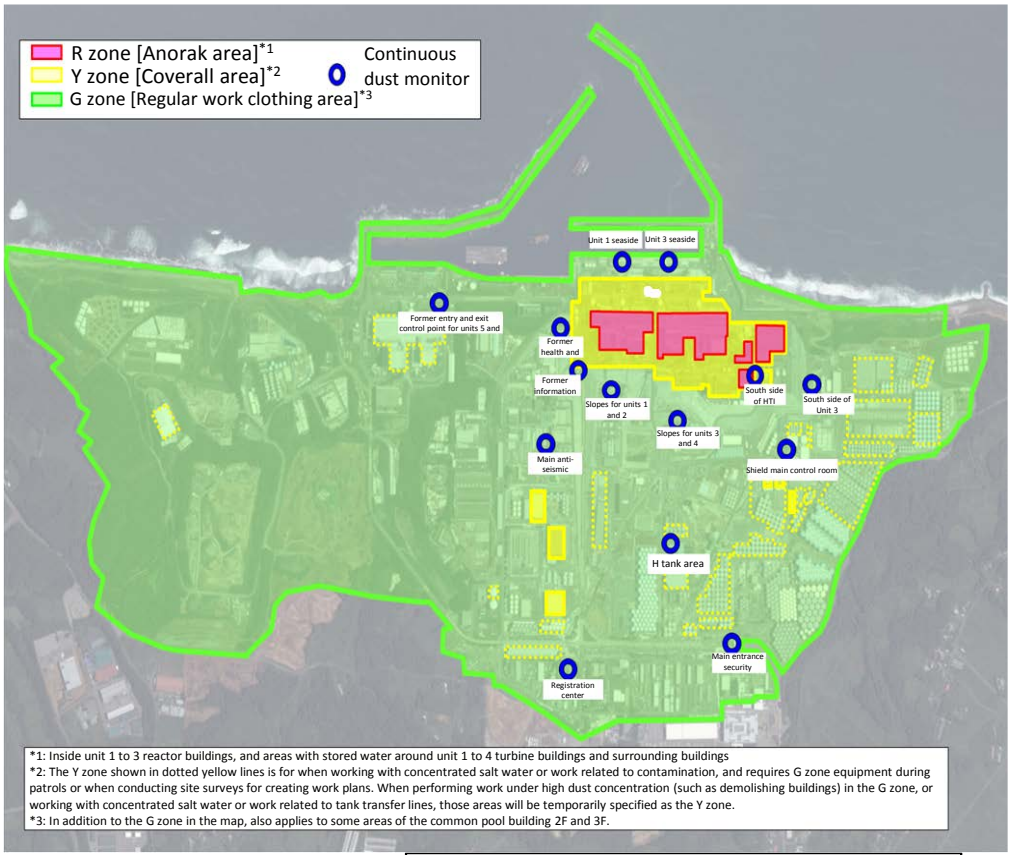
1F Site Operation Zone Control

(1) 1F site operation zone status

Present state			Zone		Protective Equipment
Areas subject to control	Areas requiring the wearing of a full-face mask	Heavily contaminated areas	**Red zone (Anorak areas)** - Inside unit 1 to 3 reactor buildings - Area with stagnant 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
		Beta areas (areas where exposure to beta rays must be considered)	**Yellow zone (Coverall 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 - Coverall - Work boots (for Y zone) - Helmet (for Y zone) - Cotton gloves + rubber gloves
		Other than above		- Around unit 1 to 4 buildings - 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
	Areas not requiring the wearing of a full-face mask		**Green zone (Regular uniform areas)** Areas except the above.		- D2 mask - Site clothing, regular work clothing*3 - Work boots (for G zone) - Helmet (for G zone) - Cotton gloves + rubber gloves or work gloves
	Areas subject to control that are free from 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



Source: Japan Space Imaging Corporation, ©DigitalGlobe

Material provided by Tokyo Electric Power Company Holdings, Incorporated.

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	
30-01-01	RB	1	Radiation control data collection methods for accurately calculating radiation exposure dose	--	--	--	
30-01-02	RB	1	Radiation control data collection methods for accurately calculating radiation exposure dose	--	--	--	
30-01-03	RB	5	Radiation control data collection methods for accurately calculating radiation exposure dose	--	--	--	
30-02	RB	1	Radiation exposure dose reduction by installing energy-efficient, wireless monitors and utilizing the measurement data	--	79.0	79.0	
30-03-01	RB	3	Shielding during installation of remote-controlled equipment	--	--	--	21.0/8.0→1.0/4.0mSv/h
30-03-02	RB	3	Shielding during installation of remote-controlled equipment	--	--	--	2.5/13.0/3.5→1.5/0.7/1.7mSv/h
30-03-03	RB	5	Shielding during installation of remote-controlled equipment	--	--	--	
30-04	RB	3	Surveys of reactor building 5 FL (the operating floor) using robots	55.0	34.4	20.6	
30-05	RB	5	Surveys of reactor building 5 FL (operating floor) using robots	55.0	34.4	20.6	
30-06	RB	5	Radiation exposure dose reduction by installing energy-efficient, wireless monitors and utilizing the measurement data	--	79.0	79.0	
30-07	Z	5	Radiation control data collection methods for accurately calculating radiation exposure dose	--	--	--	
30-08	RB	1	Reduction in work time by fabricating and installing a protective sheet	--	--	--	
30-09	RB	7	Exposure equalization for workers involved in removing rubble from Unit 1 reactor building operating floor	--	--	--	
30-10	R	3	β ray shielding when cutting flange-type tank side plates or other sheets	50	9.40	40.6	Exposure of eye lens/skin from β rays
30-11	R	4	Laser decontamination when disassembling flange-type tanks	--	46/unit	46/unit	Exposure of eye lens/skin from β rays
30-12	R	7	Change in number of mounting fixtures of flange-type tank side plates	55.0	21.0	34.0	Exposure of eye lens/skin from β rays
30-13	R	7	Improvements to disassembly method for disassembling flange-type tanks	--	0.012/unit	--	
30-14-01	R	7	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof	17,621.0	1,578.0	16,043.0	
30-14-02	RB	3	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof	17,621.0	1,578.0	16,043.0	
30-14-03	Z	1	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof	17,621.0	1,578.0	16,043.0	
30-14-04	Z	7	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof	17,621.0	1,578.0	16,043.0	
30-15-01	Z	7	Exposure simulation / contamination visualization	--	--	--	
30-15-02	Z	7	Exposure simulation / contamination visualization	--	--	--	

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

Good Practices in Radiation Exposure Dose Reduction Measures

No.	30-01-01

Title	Radiation control data collection methods for accurately calculating radiation exposure dose
Work location	Each reactor building, others
Overview	Radiation control data collection and utilization for accurately assessing construction results such as decontamination or construction planning that includes radiation exposure dose reduction measures

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

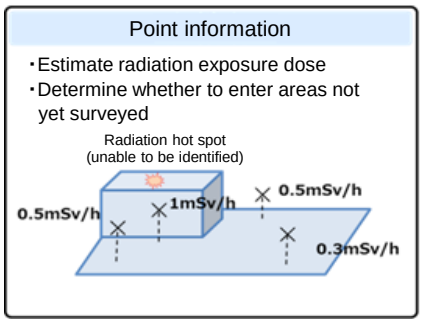
Good Practice Description

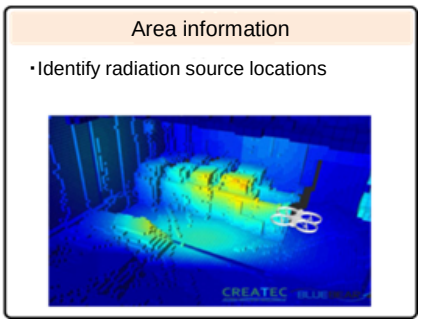
Before Implementation

Point information (2D) was used for planning as part of the radiation exposure estimates.

Implementation Details

More accurate data collection allowed radiation sources to be identified or 3D information to be used.





<RISER>

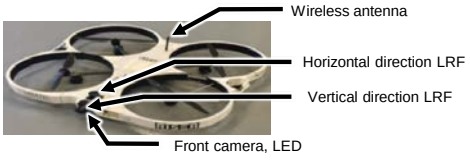
・Use aerial drones capable of operating in environments with no GPS (see No. 30-01-02 for details)

・Create 3D restoration maps and contamination maps in real time

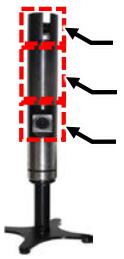
<Gamma Imager>

• Acquire point group data, gamma radiation source location, dose rate

• Create 360 x 180 degree panoramic images



Create contamination map, dose rate map at any height in the air based on acquired data from the analysis using the N-Visage system*



<Gamma Imager>

Point group data | Contamination map | Dose rate map

* Technology provided by Sellafield in the UK (SL) based on technology agreement with SL

Edited by: Japan Environment Research Co., Ltd.

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.	30-01-02

Title	Radiation control data collection methods for accurately calculating radiation exposure dose
Work location	Unit 3 reactor building
Overview	Radiation control data collection and utilization for accurately assessing construction results such as decontamination or construction planning that includes radiation exposure dose reduction measures

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

Good Practice Description

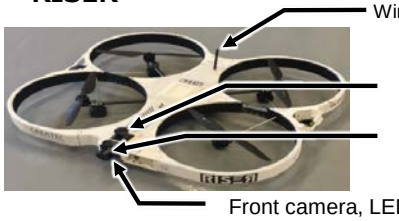
Before Implementation

Point information (2D) was used for planning as part of radiation exposure estimates.

Implementation Details

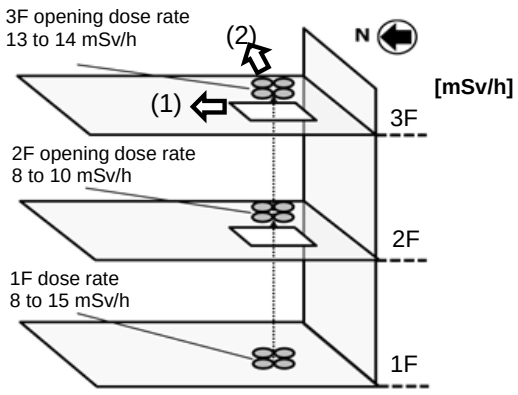
More accurate data collection allowed radiation sources to be identified or 3D information to be used.

RISER



Detector	CZT semiconductor detector ~2500 mSv/h
Dimensions	W930 x D830 x H160 mm
Weight	Approx. 4 kg
Flying time	Approx. 15 mins
Camera	HD camera x2 (forward, down)
Equipped sensors	LRF (vertical, horizontal), acceleration sensor

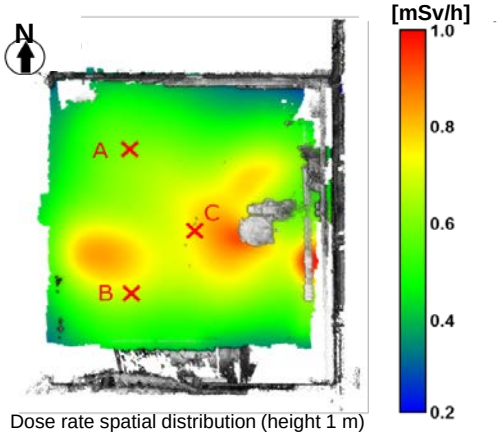
■1F to 3F of Unit 3 Reactor Building



Dose rate measurement

Photo views (1) and (2)

■Unit 3 backwashing valve pit



Dose rate spatial distribution (height 1 m)

Measurement Point	Assessment Result Using RISER	Measurement Result from Survey Meter
A	0.6	0.5
B	0.6	0.6
C	0.8	0.7

(unit: mSv/h)

Edited by: Japan Environment Research Co., Ltd.

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.	30-01-03

Title	Radiation control data collection methods for accurately calculating radiation exposure dose
Work location	Unit 2 turbine building
Overview	Radiation control data collection and utilization for accurately assessing construction results such as decontamination or construction planning that includes radiation exposure dose reduction measures

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

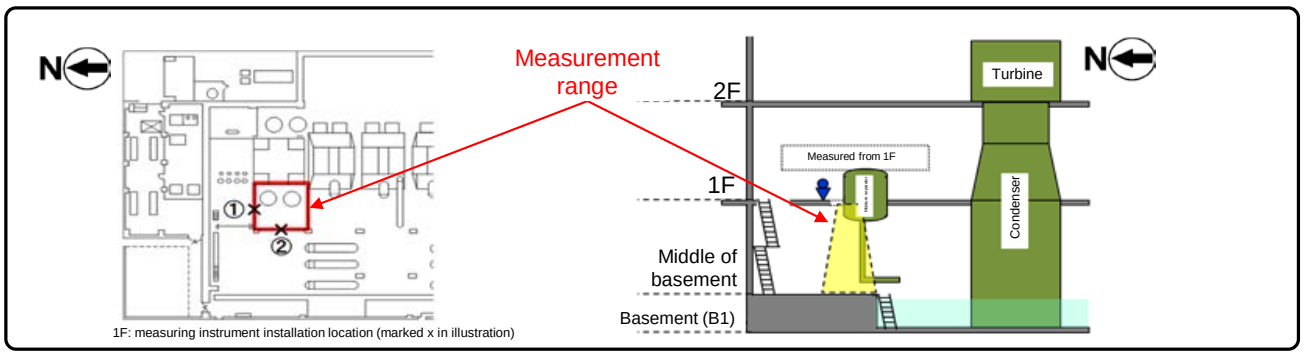
Good Practice Description

Before Implementation

Point information (2D) was used for planning as part of radiation exposure estimates.

Implementation Details

More accurate data collection allowed radiation sources to be identified or 3D information to be used.

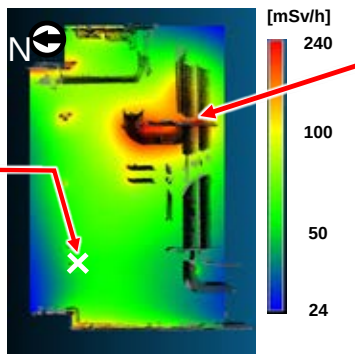


1F: measuring instrument installation location (marked x in illustration)

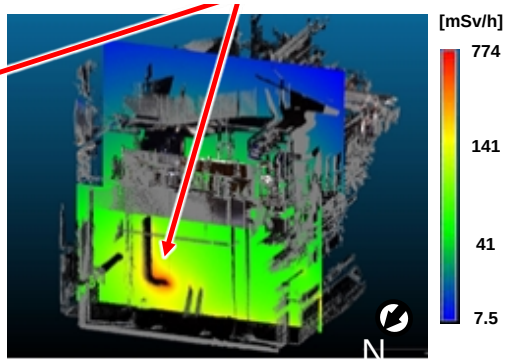
Moisture separator drain line

Analysis

[Reference] Measurement 140 mSv/h



Dose rate planar distribution [height 1 m from floor]



Dose rate vertical distribution

The basement air radiation exposure dose is highest at the moisture separator drain line, but some equipment, piping and other parts are also main radiation sources

Edited by: Japan Environment Research Co., Ltd.

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.	30-02

Title	Radiation exposure dose reduction by installing energy-efficient, wireless monitors and utilizing the measurement data
Work location	Unit 2 reactor building 1FL in front of X-6
Overview	The installation of energy-efficient, wireless monitors aimed at reducing radiation exposure of radiation workers not only reduces their exposure, but also aids visualization based on collected data that can be used for site management.

Assessment (qualitative/quantitative)	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv)	--	79
	Person time (person-days)	--	--

Good Practice Description

Before Implementation

Radiation workers who take measurements and manage the working environment account for 10% of workers with the highest radiation exposure.

Implementation Details

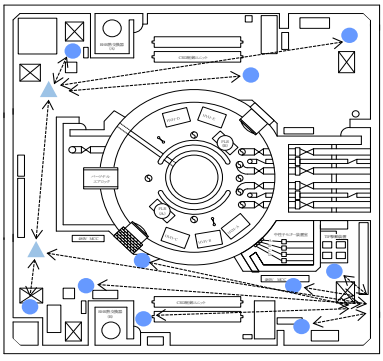
The development and installation of energy-efficient, wireless monitors aims to reduce radiation exposure of radiation workers, and also aids visualization based on collected data that can be used for site management.

- **Assumptions**
  Operates using batteries, continuation of wireless communications
- **Feedback from radiation workers:**
  - ① **Can we have longer operating devices?** ⇒ **Batteries do not need to be replaced for at least half a year!**
  - ② **At what intervals do batteries need to be replaced?** ⇒ **Inconvenient if we cannot use them when we want to!**
  - ③ **Poor conditions inside the reactor building!** ⇒ **Both inside and outside the building!**
  - ④ **More intuitive reading of dose equivalent rate!** ⇒ **Easy to see with dose map**


Monitoring PC

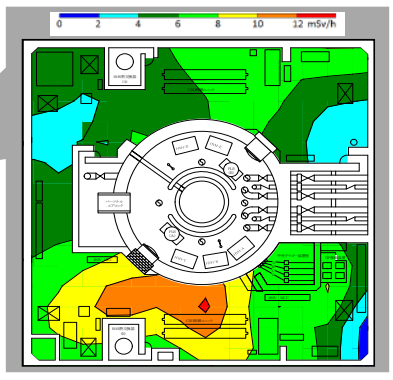
Installed work location monitors

* Si semiconductor detector



[Standby area]


Monitoring PC



- **Wireless radiation monitor**
- **Relay**

Edited by: Japan Environment Research Co., Ltd.

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.	30-03-01

Title	Shielding during installation of remote-controlled equipment
Work location	Unit 1 reactor building at various locations on 5 FL (the operating floor)
Overview	To remove rubble and other waste scattered about the operating floor using remote-control methods, power and communications equipment needs to be installed at locations around the reactor building to enable remote operations.

Assessment (qualitative/quantitative)	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	21.0/8.0	1.0/4.0
		Person time (person-days)	--	--

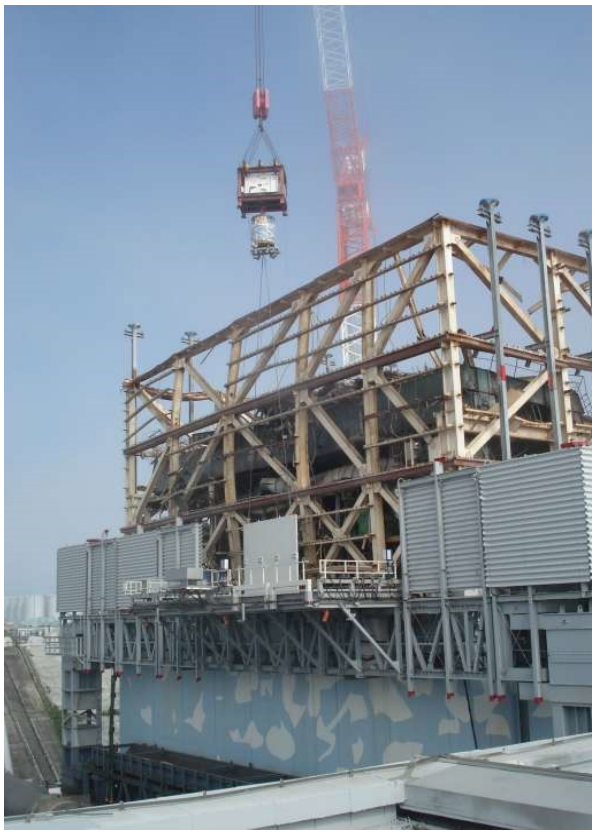
Good Practice Description

Before Implementation

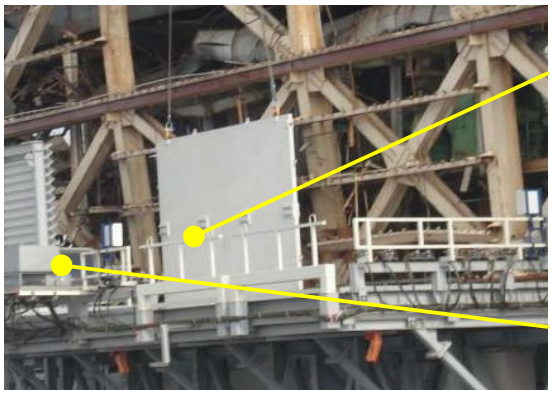
There was a high dose rate at various locations on the work floor.

Implementation Details

Installing shielding on all sides is not possible due to the strength of the beams, so a crane was used to hoist shielding panels around the work location to reduce the dose rate.



Shielding conditions on south side of work area



Before → After shielding
21.0 mSv/h
↓
1.0 mSv/h

Before → After shielding
8.0 mSv/h
↓
4.0 mSv/h

Reduction in dose rate around the work area

Shielding panel thickness: 80 mm

Edited by: Japan Environment Research Co., Ltd.

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.	30-03-02

Title	Shielding during installation of remote-controlled equipment
Work location	Unit 1 reactor building at various locations on 5 FL (the operating floor)
Overview	To remove rubble and other waste scattered about the operating floor using remote-control methods, power and communications equipment needs to be installed around the reactor building to enable remote operations.

Assessment (qualitative/quantitative)	Effects	Before Implementation	After Implementation
	Dose rate (mSv/h)	2.5/13.0/3.5	1.5/0.70/1.7
	Person time (person-days)	--	--

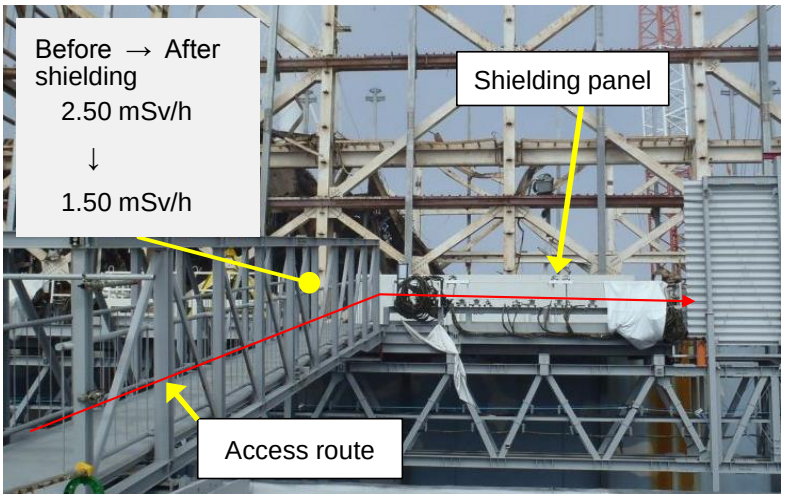
Good Practice Description

Before Implementation

There was a high dose rate at various locations on the work floor.

Implementation Details

Shielding installed at a location of the work area.



Shielding panel conditions on east side of work area

Edited by: Japan Environment Research Co., Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	30-03-03

Title	Shielding during installation of remote-controlled equipment
Work location	Unit 1 reactor building at various places on 5 FL (the operating floor)
Overview	To remove rubble and other waste scattered about the operating floor using remote-control methods, power and communications equipment needs to be installed around the reactor building to enable remote operations.

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

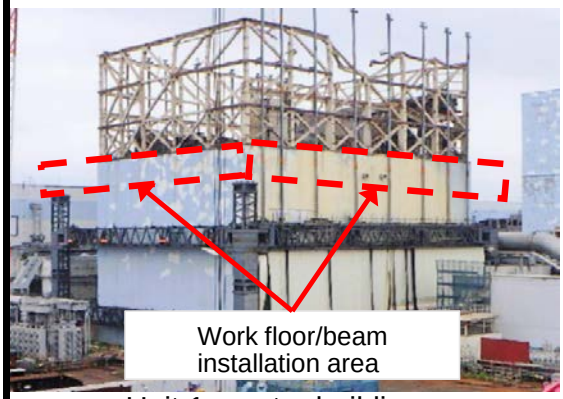
Good Practice Description

Before Implementation

Dose rate was unknown when installing the work floor.

Implementation Details

A measurement instrument was hoisted up using a large crane to measure the air dose rate in the location where the work floor was to be installed.

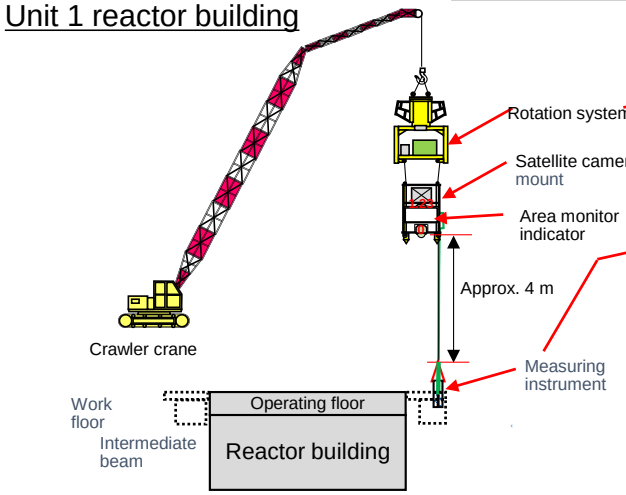


Unit 1 reactor building

Dose rate measurement results

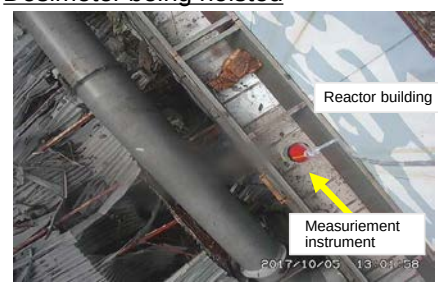
Top of east work floor ~18.9 mSv/h
Inside intermediate east beam ~3.9 mSv/h
Top of south work floor ~19.3 mSv/h
Inside intermediate sound beam ~10.1 mSv/h
Inside access bridge ~ 3.3 mSv/h

Determine radiation exposure dose environment before work
- Calculate expected dose rate
- Update radiation exposure dose reduction measures



Dose rate measurement illustration

Dosimeter being hoisted



Dose rate measurement conditions (taken from satellite camera)

Measurement of dose rate within the work area

Edited by: Japan Environment Research Co., Ltd.

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.	30-04

Title	Surveys of reactor building 5 FL (the operating floor) using robots
Work location	Unit 2 reactor building 5 FL (the operating floor)
Overview	Lead shielding for the inspection area of robots used for measuring dose rate and contamination concentration and making other measurements on 5 FL (operating floor) of the reactor building

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	55.01	34.38
		Person time (person-days)	--	--

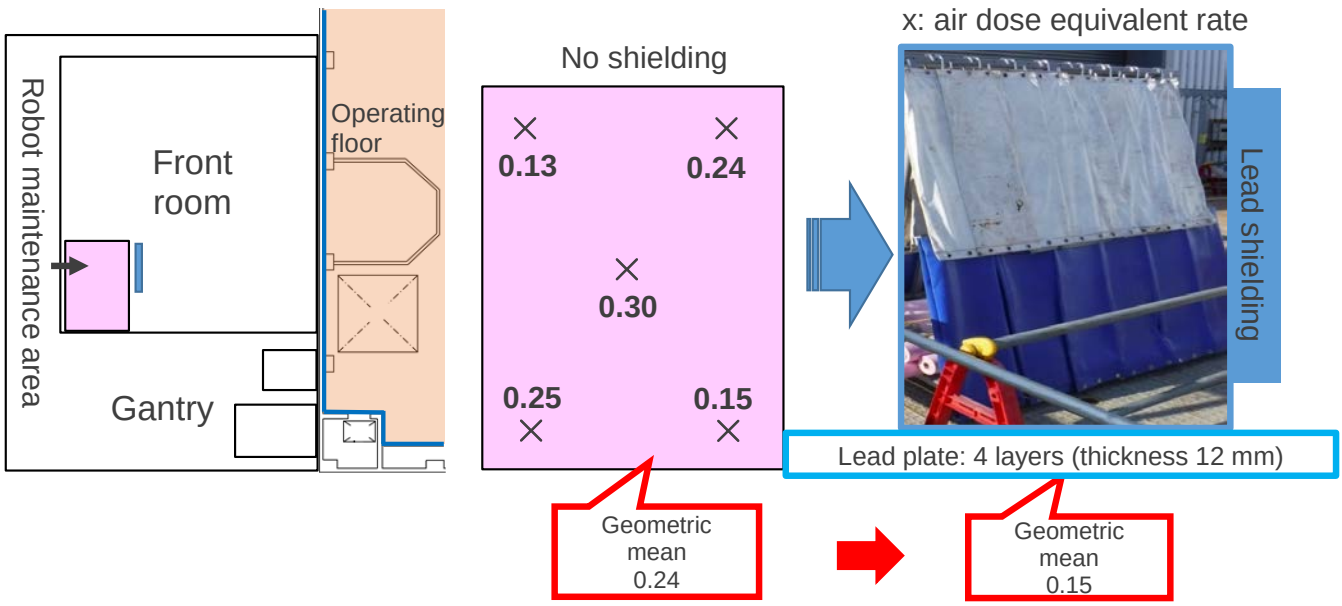
Good Practice Description

Before Implementation

There was a high dose rate within the robot maintenance area.

Implementation Details

Shielding was installed in the robot maintenance area.



Effects of lead shielding	No shielding	With shielding
Maintenance area dose equivalent rate geometric mean	0.24	0.15
Exposure from June 23 to July 20 (work in maintenance area)	55.01	34.38

20.63 work-mSv reduction in exposure

Edited by: Japan Environment Research Co., Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	30-05

Title	Surveys of reactor building 5 FL (operating floor) using robots
Work location	Unit 2 reactor building 5 FL (the operating floor)
Overview	In addition to robots, the RMS*) was also used for measuring dose rate and contamination concentration and making other measurements on 5 FL (the operating floor) of the Unit 2 reactor building,.

Assessment (qualitative/(quantitative))

Effects	Before Implementation	After Implementation
Radiation exposure dose (mSv)	55.01	34.38
Person time (person-days)	--	--

*) Remote Monitoring System

Good Practice Description

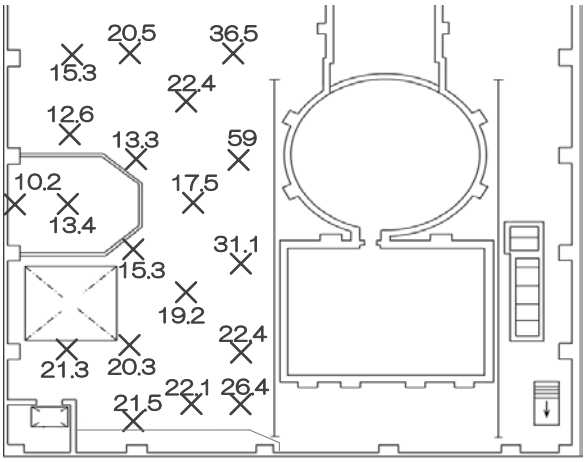
Before Implementation

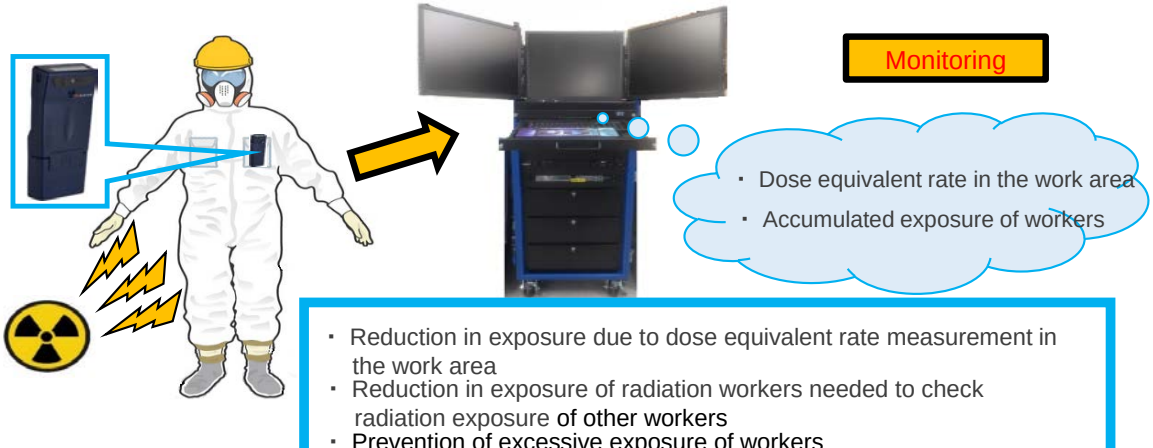
Examining conditions on the operating floor manually was expected to result in an extremely high level of exposure.

Implementation Details

Robots/RMS were used for measuring dose rate and contamination concentration and making other measurements on the operating floor.

x: measurement location





- Reduction in exposure due to dose equivalent rate measurement in the work area
- Reduction in exposure of radiation workers needed to check radiation exposure of other workers
- Prevention of excessive exposure of workers

Edited by: Japan Environment Research Co., Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

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

No.	30-06

Title	Radiation exposure dose reduction by installing energy-efficient, wireless monitors and utilizing the measurement data
Work location	Unit 2 reactor building 1FL in front of X-6
Overview	The installation of energy-efficient, wireless monitors aimed at reducing radiation exposure of radiation workers not only reduces their exposure, but also aids visualization based on collected data that can be used for site management.

Assessment (qualitative (quantitative))

Effects	Before Implementation	After Implementation
Radiation exposure dose (mSv)	--	79
Person time (person-days)	--	--

Good Practice Description

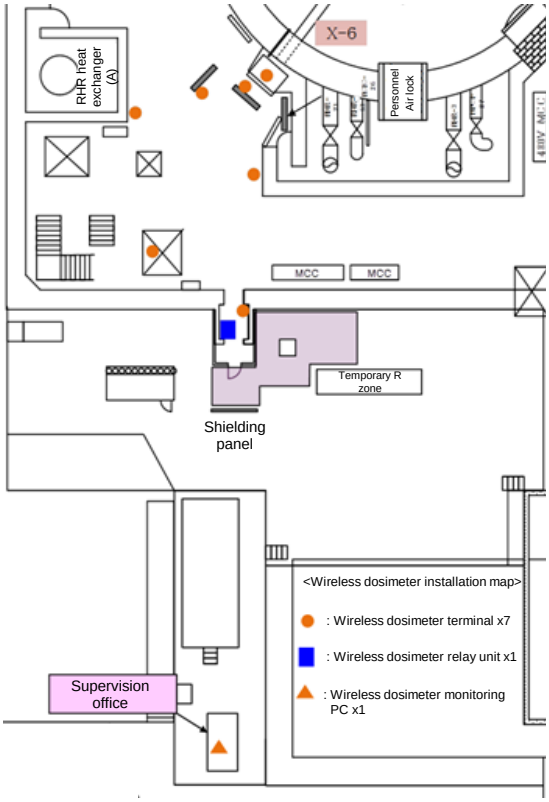
Before Implementation

Radiation workers who take measurements and manage the working environment account for 10% of workers with the highest radiation exposure.

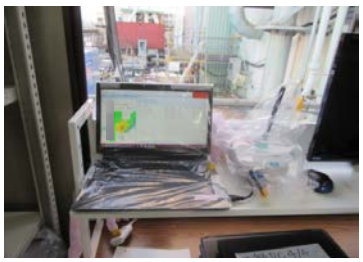
Implementation Details

The development and installation of energy-efficient, wireless monitors aims to reduce radiation exposure of radiation workers, and also aids visualization based on collected data that can be used for site management.

Example of use in a work



Constantly monitoring the air dose equivalent rate from the work area supervision office



Inside the work area supervision office (monitoring PC)

Dose map display (real time)

Dosimeter data display

Edited by Japan Environment Research Co., Ltd.

Good Practices 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 ( )	(Z)		6	Preventing spread of contamination	
			7	Other	

No.	30-07

Title	Radiation control data collection methods for accurately calculating radiation exposure dose
Work location	All 1F building areas
Overview	Radiation control data collection and utilization for accurately assessing construction results such as decontamination or construction planning that includes radiation exposure dose reduction measures

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

Good Practice Description

Before Implementation

During piping installation work, it was likely that there would be greater radiation exposure of construction supervisors.

Implementation Details

Construction supervision using the Remote Monitoring System (RMS) helps to reduce exposure of construction supervisors

Overview of RMS

It consists of the IP camera, headset and remote monitoring APD.

Amount of reduction in radiation

Company	Period (No. of Work Days)	Geometric Mean of Work Area (mSv/h)	Effects (Time (minutes))	Amount of Exposure Reduced (person-mSv)
Company A	2018.4.19 - 2018.7.27(72)	0.238	0.67(40)	11.42
Company B	2018.6.5 - 2018.7.31(35)	0.294	0.33 (20)	3.43
Company C	2018.8.7 - 2018.10.15(43)	0.294	0.33 (20)	4.21

Edited by: Japan Environment Research Co., Ltd.

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.	30-08

Title	Reduction in work time by fabricating and installing a protective sheet
Work location	Unit 1 reactor building at various locations on 5 FL (operating floor)
Overview	To remove rubble and other waste scattered about the operating floor using remote-control methods, power and communications equipment needs to be installed around the reactor building to enable remote operations.

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

Good Practice Description

Before Implementation

Cables installed outside need to be protected with weather and flame resistant sheets, however there was the risk of exposure under high dose rates.

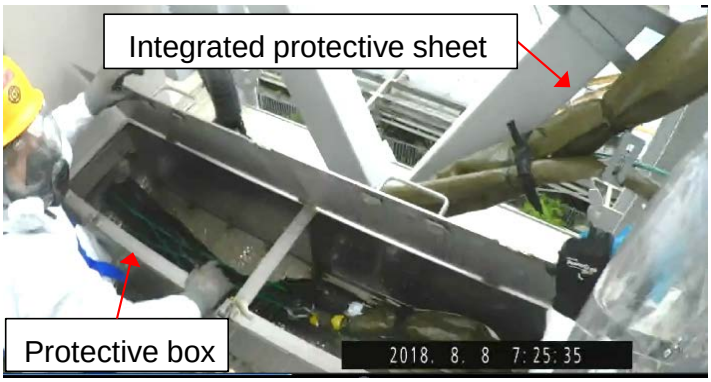
Implementation Details

The integrated weather and flame resistant protective sheet was fabricated to reduce the time required for installing protection.

- Cables require protection by using weather and flame resistant protective sheets
- Find ways to reduce work time under high dose rates

Boxes constructed for protection of cable joints

Fabricate an integrated weather and flame resistant protective sheet



Integrated protective sheet and protective box

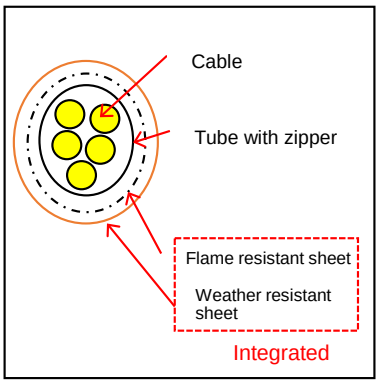


Illustration of cable protection

* Boxes were also constructed for cable joints to make work easie

Edited: Japan Environment Research Co., Ltd.

Good Practices 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.	30-09

Title	Exposure equalization for workers involved in removing rubble from Unit 1 reactor building operating floor
Work location	1F Unit 1 reactor building, others
Overview	The large number and variety of different work locations and the different dose rate environments in each location made it difficult to achieve exposure equalization for workers. A worker allocation plan was created and utilized to change the work location depending on each worker's exposed dose rate and as a result there were no workers who exceeded 20 mSv/year exposure.

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

Good Practice Description

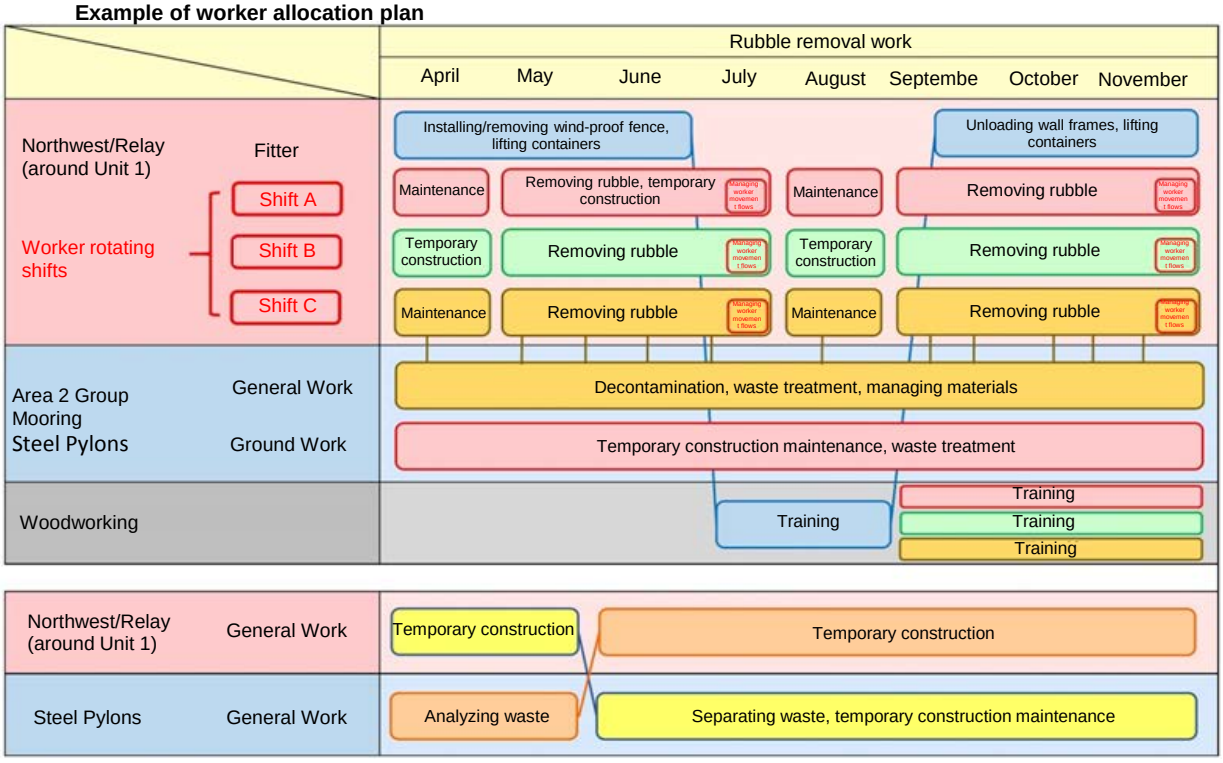
Before Implementation

Exposure generally becomes higher with workers who had become accustomed to the site, and there was the risk of approaching the 20 mSv/year limit.

Implementation Details

Workers were regularly checked for amount of exposure, and a worker allocation plan was created and utilized to change the work location depending on each worker's exposed dose rate.

Example of worker allocation plan



■ **Achievements**

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

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

■ **Future challengers**

(1) Even with rotating shifts, worker allocations remain uneven due to work they are more skilled at or have less experience with. As a result, dose exposures may not be spread out evenly between individual workers.

→ Continue implementing worker allocation plans

(2) Many equipment failures meant scheduled work could not be completed, resulting in unexpected increases in exposures.

(3) Worker movement flows were finalized, however there were a number of repeat cases where workers doing tasks that differed to the plans would have to move through areas with high dose rates in the event of an evacuation.

→ Continue managing movement

Edited by: Japan Environment Research Co., Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

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	

No.	30-10

Title	β ray shielding when cutting flange-type tank side plates or other sheets
Work location	1F building area equipment storage
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (Sv)	50 (β ray)	9.4 (β ray)
		Crystal exposure (mSv/year)	83	2.8

Good Practice Description

Before Implementation

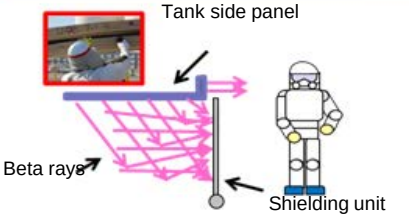
There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

Acrylic sheet and rubber sheet were used to shield against individual energy β rays.

Specific radiation exposure dose reduction measures

Sid panel Shielding when removing protective



Portable molded shielding

Shielding when installing mounting fixtures

Shielding when opening holes in bottom plate

Shielding during container storage operations

Edited by: Japan Environment Research Co., Ltd.

Good Practices in Radiation Exposure Dose Reduction Measures

Location			Category		
Inside reactor building	RB	R	1	Time	4
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.	30-11

Title	Laser decontamination when disassembling flange-type tanks
Work location	1F building tank yard
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	-46/tank (β ray)
		Person time (person-days)	--	--

Good Practice Description

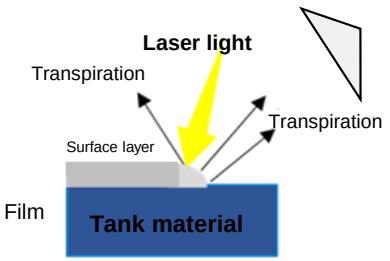
Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

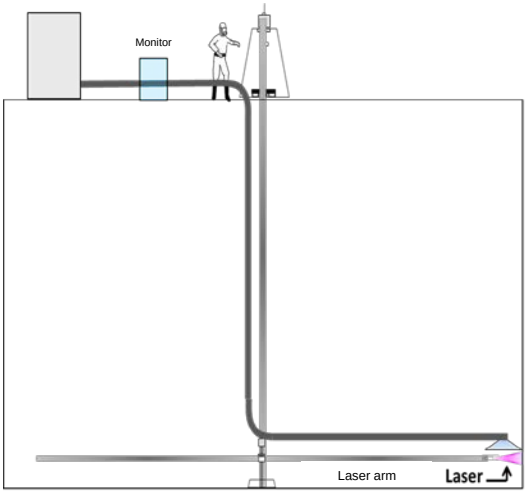
Laser decontamination is being used to reduce exposure to β rays adhered to the surface of the tanks, and workers wear face guards to reduce exposure of eye lens.

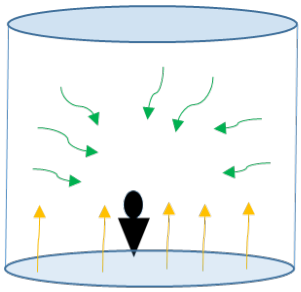
Image of laser decontamination



Surface layer (film) and material transpiration due to laser irradiation

Exhaust system





Effects of radiation inside tank (illustration)

Radiation from bottom

Radiation from side plate

Radiation from side plate → (green) was reduced significantly after laser decontamination

Better shielding against β rays with face guard

Acrylic 3 mm β γ 5.0 → 1.0 mSv/h

Acrylic 10 mm aiming for β γ 1.0 → 0

Edited by: Japan Environment Research Co., Ltd.

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.	30-12

Title	Change in number of mounting fixtures of flange-type tank side plates
Work location	1F building area equipment storage
Overview	Originally, the method implemented at the work site installed mounting fixtures in sets of 4 sheets, however this was changed to Toyota's Kaizen method of installing each sheet individually to eliminate material delivery waiting time.

Assessment (qualitative / (quantitative))	Effects	Before Implementation	After Implementation
	Radiation exposure dose (mSv/tank)	55 (average before improvement)	21
	Forehead exposure (mSv/year)	--	1.2

Good Practice Description

Before Implementation

Mounting fixtures were installed in sets of 4 sheets.

Implementation Details

As a result of implementing Toyota's Kaizen method, installation was changed from sets of 4 sheets → 1 sheet/set, to reduce the waiting time of workers.

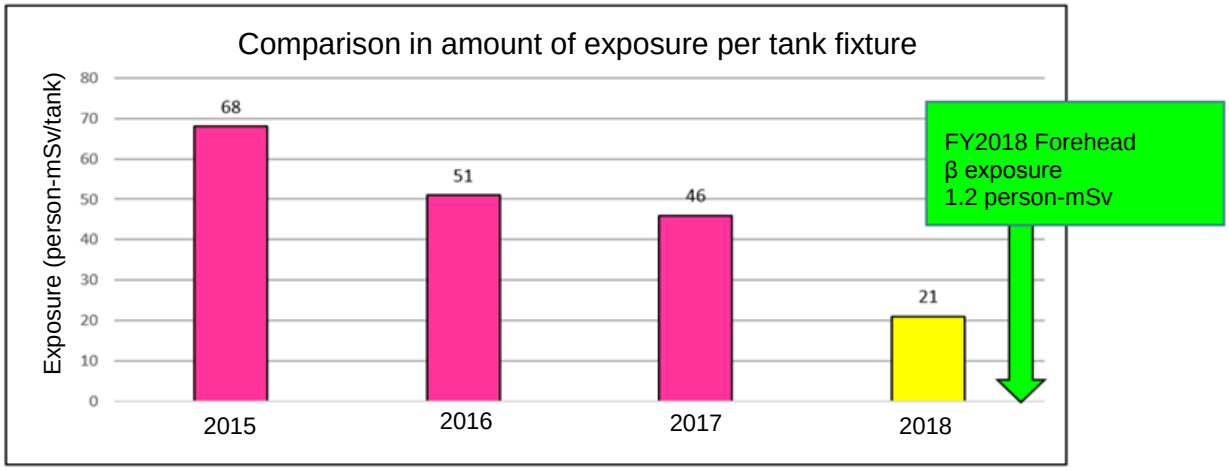
Secondary results of Toyota's Kaizen

June 2015
Start of work

April 2018
Kaizen implemented

*: Forecast values for FY2018 values

FY2015 | FY2016 | FY2017 | FY2018



Reduction in work time for mounting fixture sets

4 plates

1 plate

Edited by: Japan Environment Research Co., Ltd.

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.	30-13

Title	Improvements to disassembly method for disassembling flange-type tanks
Work location	1F building tank yard
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	--	-0.012/tank
		Person time (person-days)	--	-2.2/tank

Good Practice Description

Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

Reduction of the number of workers (8/group) and the work time were implemented with the revised disassembly procedure and improved work method.

Tank plate lifting conditions

Adjustable hook

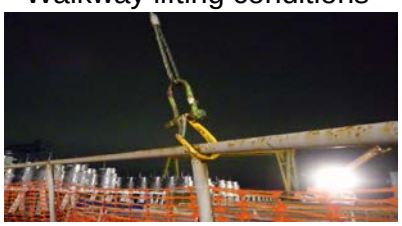
The use of an adjustable hook reduced person time per tank to approx. 0.9 person-days.

Effects of exposure reduction during disassembly were
γ ray
0.005 mSv/day x 0.9 person-days ≒ **0.005 person-mSv/tank (reduction)**

β ray
0.009 mSv/day x 0.9 person-days ≒ **0.08 person-mSv/tank (reduction)**

Walkway lifting conditions

The change in the lifting jig reduced person time per tank to approx. 1.3 person-days.



Effects of exposure reduction during disassembly were
γ ray
0.005 mSv/day x 1.3 person-days ≒ **0.007 person-mSv/tank (reduction)**

β ray
0.09 mSv/day x 1.3 person-days ≒ **0.12 person-mSv/tank (reduction)**

Edited by: Japan Environment Research Co., Ltd.

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

No.	30-14-01

Title	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof
Work location	1F outside building (Onahama district) / 1F inside building
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	17,621	1,578
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

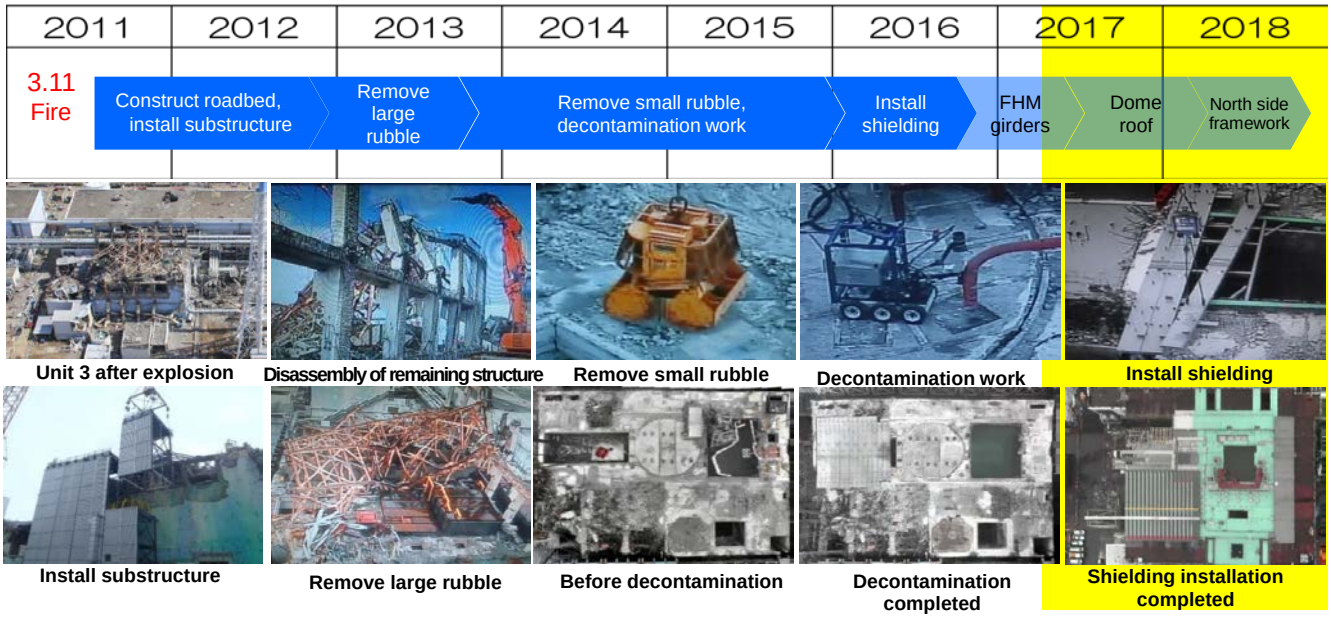
There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

--

Work undertaken in this announcement: shading

Work process and procedures



Edited by: Japan Environment Research Co., Ltd.

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

3

No. 30-14-02

Title	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof
Work location	1F outside building (Onahama district) / 1F inside building
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/quantitative)

Effects	Before Implementation	After Implementation
Radiation exposure dose (mSv)	17,621	1,578
Person time (person-days)	--	--

Good Practice Description

Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

A shielded rest area was constructed for workers to rest during work-time to reduce exposure during standby.

Unit 3 west side rest area

Inside rest area (monitor exterior conditions) (communications with quake-proof remote center)

Operating floor structure rest area (BOX culvert used)

Edited by: Japan Environment Research Co., Ltd.

Good Practices 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 ( )	(Z)		6	Preventing spread of contamination
			7	Other

1

No.	30-14-03

Title	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof
Work location	1F outside building (Onahama district) / 1F inside building
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	17,621	1,578
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

During assembly of FHM girders and dome roof, each piece of equipment was disassembled, assembled and tested for sliding off-site, and after checking operations, they were assembled and installed at 1F (pre-fabricated mock-up models).

FHM girder assembly

Separation, transportation

Re-assembly

Dome roof sliding test

Edited by: Japan Environment Research Co., Ltd.

Good Practices 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 ( )	(Z)		6	Preventing spread of contamination
			(7)	Other

No.	30-14-04

Title	Radiation exposure dose reduction measures when installing Unit 3 operating floor dome roof
Work location	1F outside building (Onahama district)
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

Assessment (qualitative/(quantitative))	Effects		Before Implementation	After Implementation
		Radiation exposure dose (mSv)	17,621	1,578
		Person time (person-days)	--	--

Good Practice Description

Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

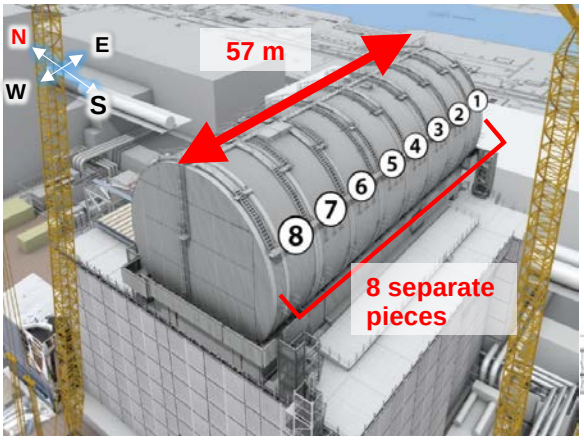
Implementation Details

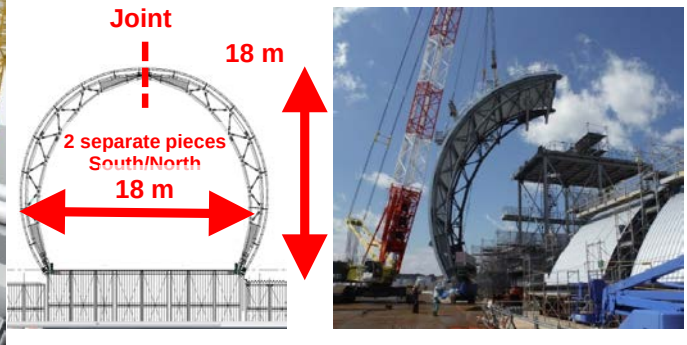
The dome roof was first assembled off-site 1F in the Onahama district (outside the restricted zone), to reduce work on the 1F site. Assembled equipment was made as large as possible.

Large main truss module

Large sub truss module

Preliminary assembly of gable wall, large module





Large dome roof module

Edited by: Japan Environment Research Co., Ltd.

Good Practices 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 ( )	(Z)		6	Preventing spread of contamination
			(7)	Other

No.	30-15-01

Title	Exposure simulation / contamination visualization
Work location	Naraha-machi community center, others
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

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

Good Practice Description

Before Implementation

There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

Implementation Details

Two videos were created and used for training because no such videos were available: "Exposure visualization" and "Contamination visualization."

Created exposure / decontamination visualization

Try it on and feel it. See what it is like!

Edited by: Japan Environment Research Co., Ltd.

Good Practices 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 ( )	(Z)		6	Preventing spread of contamination
			(7)	Other

No.	30-15-02

Title	Exposure simulation / contamination visualization
Work location	Naraha-machi Community Center, others
Overview	When cutting/disposing of flange-type tank side/bottom plates and sheets, measures to shield against high-energy β rays (2.27 MeV) were implemented due to sudden increase in exposure of eye lens/skin from β rays.

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

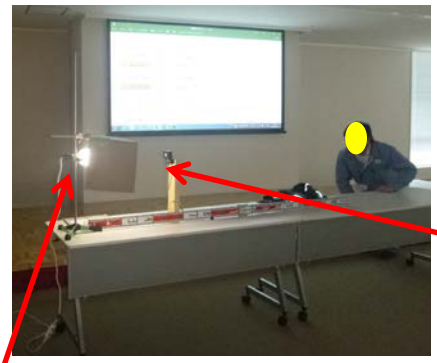
Good Practice Description

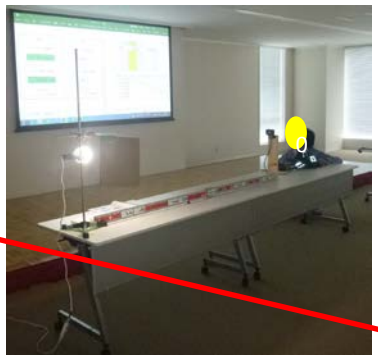
Before Implementation: There was a sudden increase in exposure of eye lens/skin from high-energy β rays.

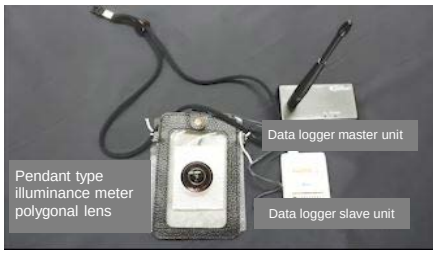
Implementation Details: A system (video) was created and used for training because no such videos were available, using an illuminance meter to simulate exposure.

Created system to show that light = radiation source → simulated

Visualization of radiation using light



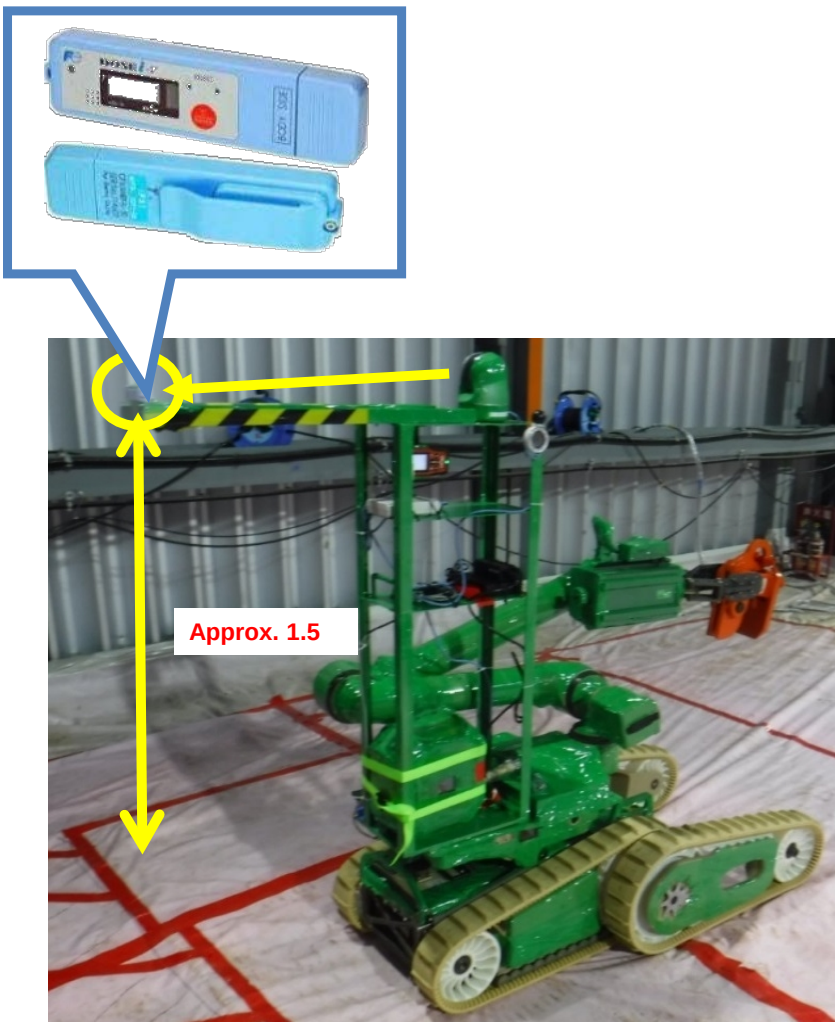




Illuminance meter = dosimeter

Light source = radiation source

Edited by: Japan Environment Research Co., Ltd.



The robot Kobra to survey the environment on 5FL (the operating floor) of the 1F-2 reactor building, and the measurement instrument used

Good Practices in Radiation Exposure Dose Reduction Measures

Issued in January, 2019

Commissioned by the Ministry of Health, Labour and Welfare

"FY2018 Project to Enhance the Radiation Exposure Dose Reduction Measures for works Relating to the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant "

Assignee: Japan Environment Research Co., Ltd.