
Unit 1 reactor building cover

Measures to reduce exposure
during work to demolish wall panels

14 November 2016

Shimizu Corporation

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1. Overview of work

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<Case 1>

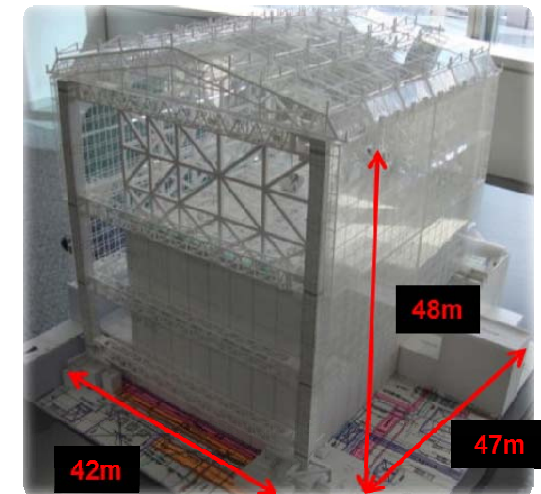
- Work name: Work to demolish reactor building cover
- Work period: 30 May 2014–20 June 2017 (Planned extension to end of August)
- Description of work: Partial demolition of reactor building cover, and other related work (6 roof panels, 18 wall panels, partial demolition of steel frame columns and beams, partial modification and reinstallation of steel frame columns and beams, and other related work)

<Case 2>

- Work name: Work to install mist spraying equipment
- Work period: 29 September 2014–31 August 2016
- Description of work: Planning and implementation relating to mist spraying equipment (Mist pipe facilities around reactor building, and other related work)

Reference: Basic specifications of building cover

- Dimensions: 47 m x 42 m x eaves height 48 m
- Main structure: Steel framed structure, column base pins/column-beam rigid joints (fitted joints)
- Roof/walls: Steel frame truss/membrane structure



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1. Overview of work

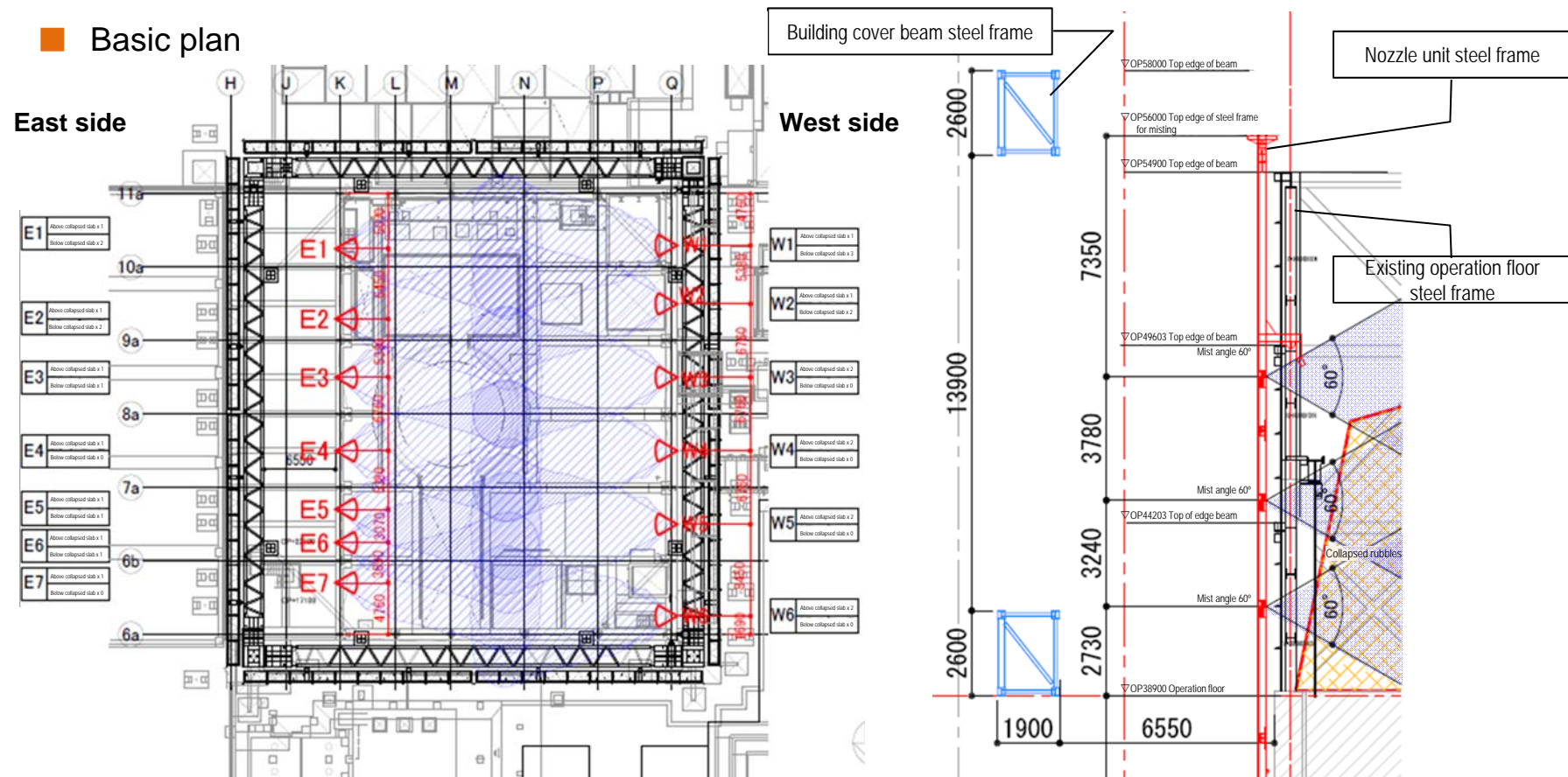
3

<Work to install mist spraying equipment>

After dismantling the building cover, rubble pieces accumulated on the reactor building operation floor will be removed.

To prepare for the possibility of radioactive dust scattering during rubble removal work, a plan was adopted for installing mist spraying equipment to suppress dispersion of radioactive dust on the existing operation floor steel frame.

Basic plan



▲ Mist spraying equipment (nozzle) layout plan and misting pattern

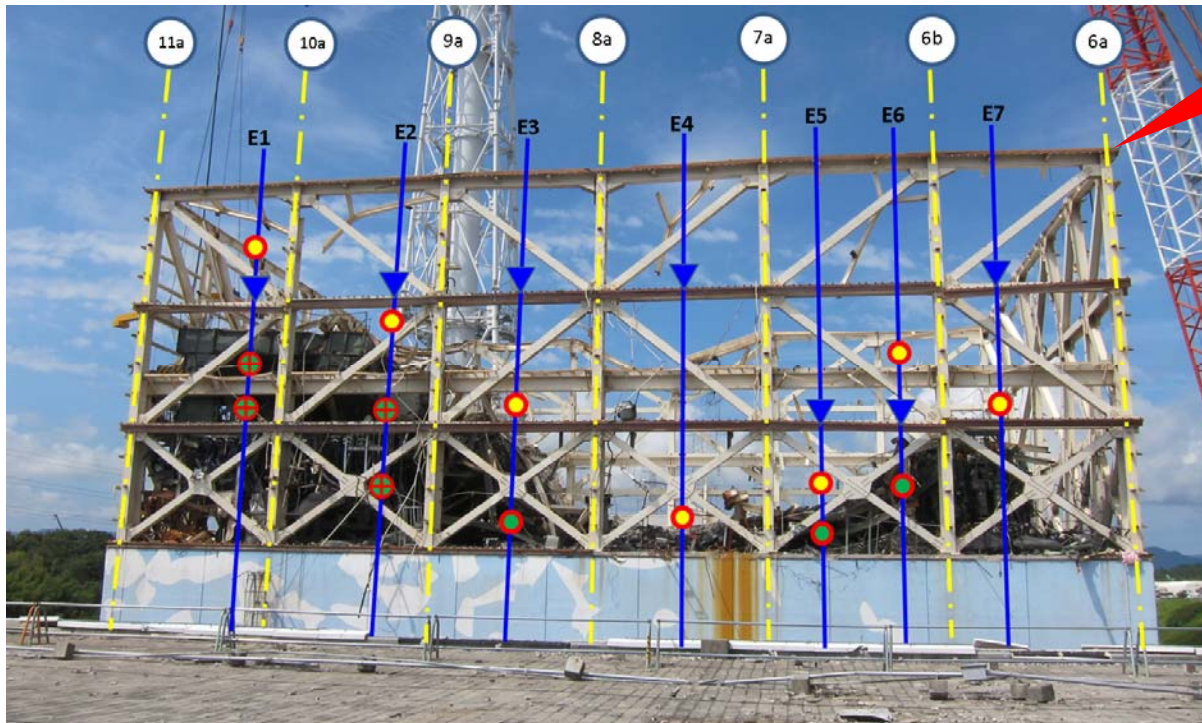
▲ Conceptual drawing of nozzle unit steel frame and misting

1. Overview of work

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<Work to install mist spraying equipment>

- Mist spraying equipment (nozzle unit steel frame) arrangement, east side

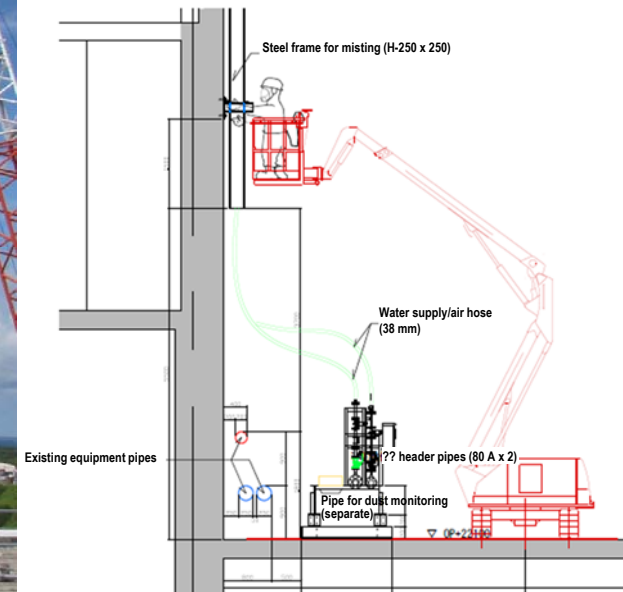


Nozzle unit steel frame

- Nozzle arrangement
- ▼ Support points
 - 60° above collapsed slab (GISM60150 II): 7 locations
 - 60° below collapsed slab (GISM60150 II): 3 locations
 - ⊕ 60° below collapsed slab (GISM60220 II): 4 locations

[Problem (1)]

Area around existing operation floor steel frame for nozzle unit installation is at a high location with high dose, and has many interfering objects.



▲ Rooftop of lower section on east side

[Problem 2]

The roof of the lower section on the east side, where there is a need for non-remote, manned work, such as connecting pipes, has a high dose.

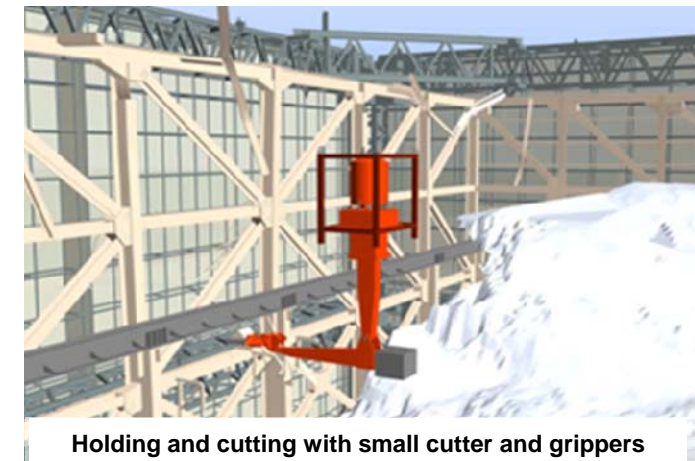
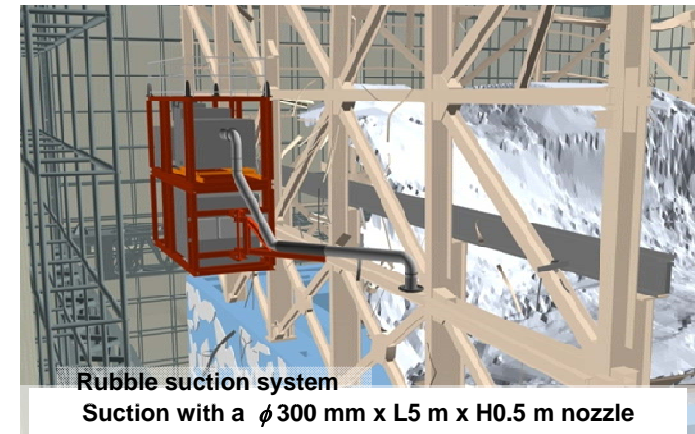
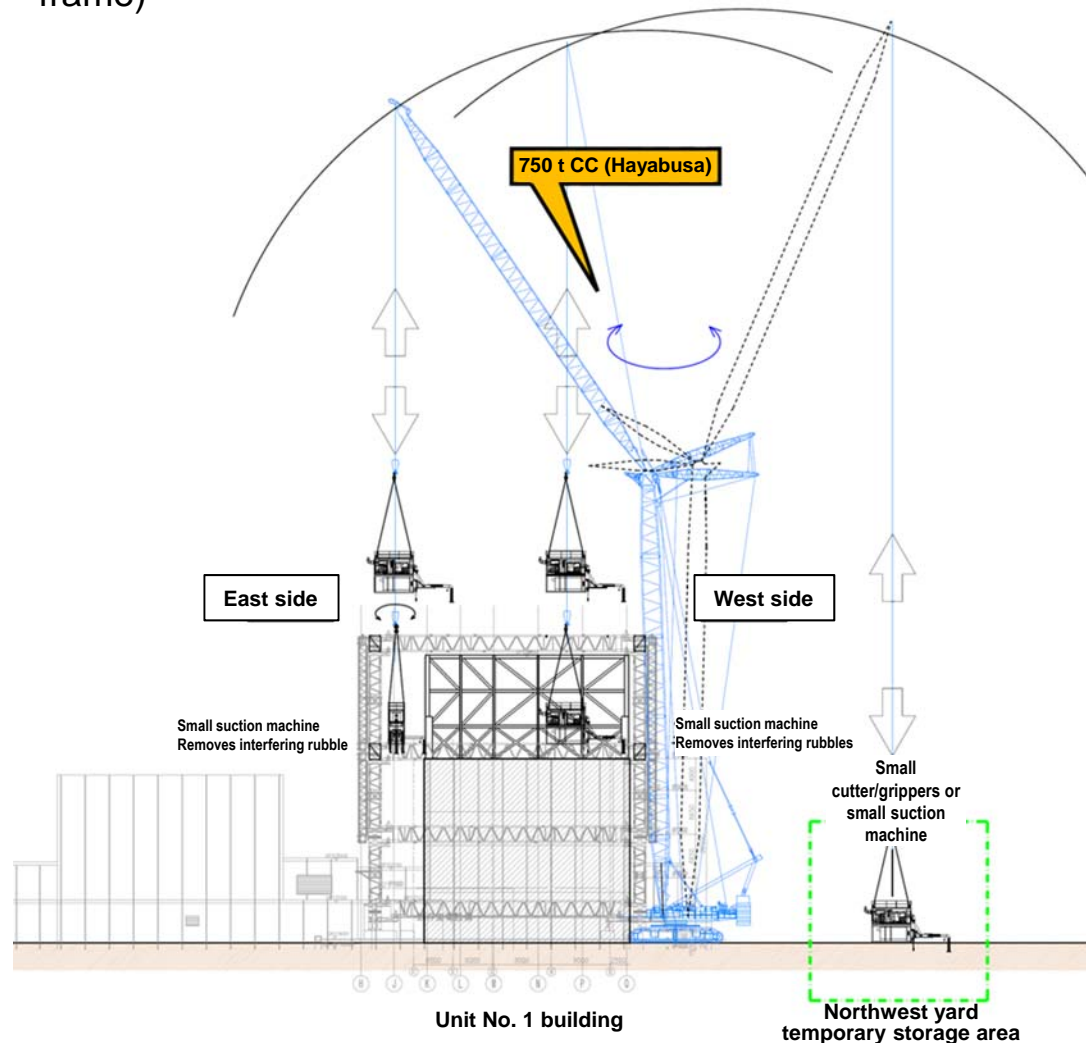
1. Overview of work

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<Work to install mist spraying equipment>

- Plan to remove interfering small rubble pieces and obstructing steel frame for installation of mist spraying equipment (nozzle unit steel frame)

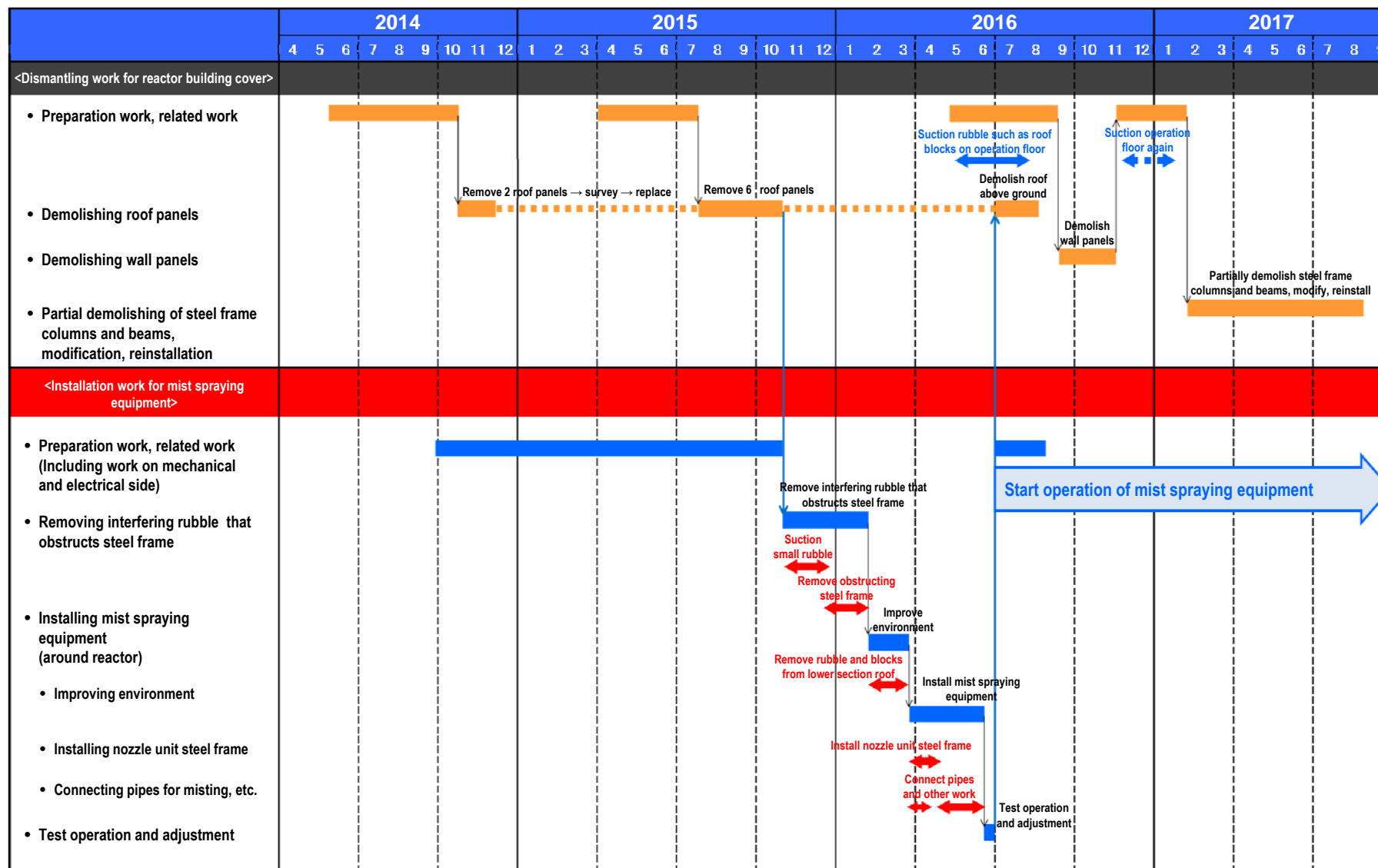
**Solution to [Problem (1)] =
Implementation of remote control**



▲ Conceptual image of removing interfering material

2. Overall process

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↔ Explained this time (exposure reduction measures)
 ↔ Same as above (implementations afterwards)

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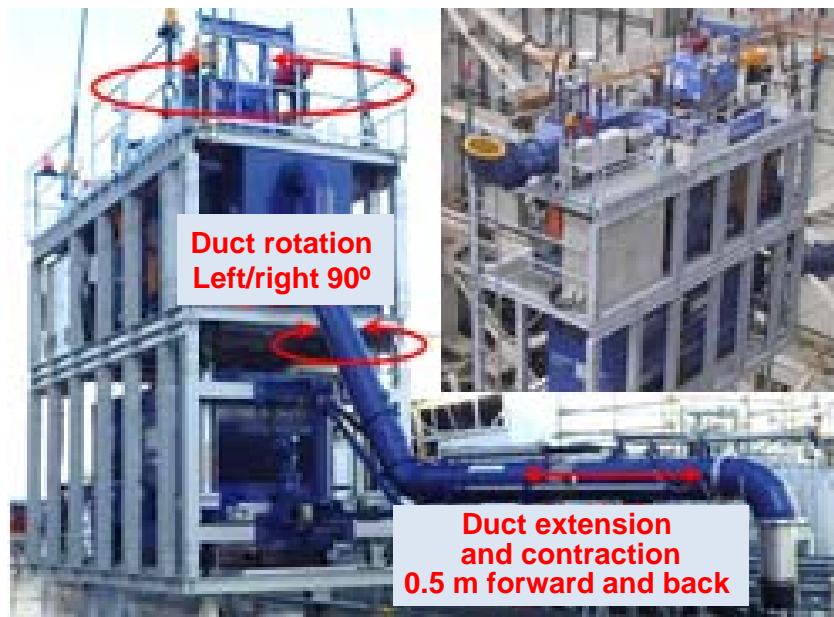
3. Measures to reduce exposure in each type of work

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1) Suction of small rubble pieces using rubble suction system “Karuwaza-1”

Due to the reactor building explosions which occurred after the earthquake, many pieces of small rubble, such as pieces of concrete, were present on the existing operation floor steel frame. These interfered with the installation of mist spraying equipment (nozzle unit steel frame), and had to be removed.

Since this is an elevated work environment with a high dose, equipment was developed to suction up the small rubble pieces through remote operation, and work was done using a remote guidance system developed at the time the cover was installed.



▲ Rubble suction system



▲ Rubble suction in progress

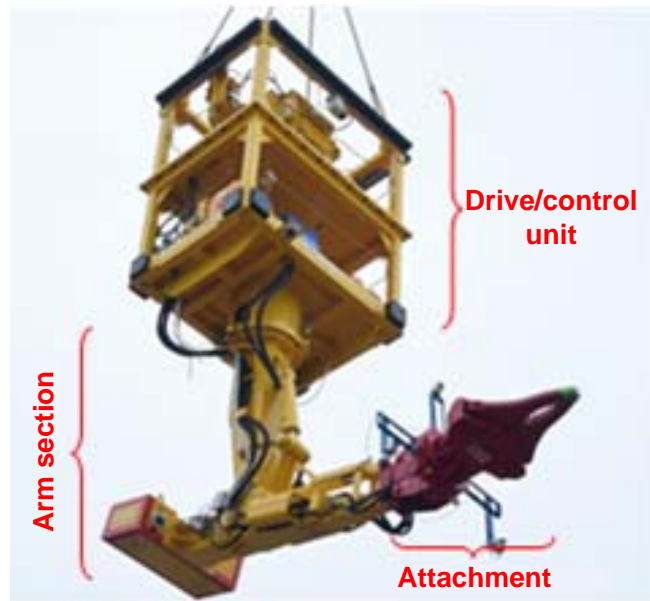
3. Measures to reduce exposure in each type of work

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2) Removal of obstructing steel frame using obstructing steel frame removal system "Hitokuchi"

In addition to small rubble pieces on top of the existing operation floor steel frame, bent steel frames, pipes and other members are entangled, and present as obstacles.

An obstructing steel frame removal system with a small cutter and grippers function was developed, and work was done through remote operation, just as in small rubble suction.



▲ Full view of equipment
(Used by suspending from crane)
Weight: Approx. 18 t
Drive system: Hydraulic

Small cutter ▼



▲ Small grippers

3. Measures to reduce exposure in each type of work

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3-1) Installation of mist spraying equipment (installation of nozzle unit steel frame)

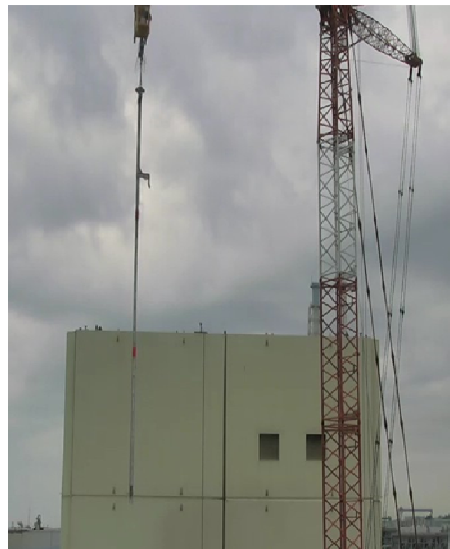
Basic assembly and unit integration of the nozzle unit steel frame of the mist spraying equipment (with pre-installed vertical pipe) were carried out in an area with a comparatively low dose, and in mounting to the existing operation floor steel frame, all work was done remotely using a remote guidance system.



▲ Basic assembly of nozzle unit steel frames



▲ Nozzle unit steel frame installation
(East side) (East side 7 locations, west side 6 locations)



▲ Installation of nozzle unit steel frame using remote guidance system



3. Measures to reduce exposure in each type of work

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3-2) Installation of mist spraying equipment (connecting pipes and other work)

Some non-remote manned work was necessary on the roof of the lower section of the reactor building, such as installation of a horizontal pipe unit and connection of pipe with the nozzle unit steel frame.

On the pertinent rooftop, the atmospheric dose was high due to dispersion of small rubble pieces in the explosion after the earthquake, and thus **the environment was improved by removing small rubble pieces, roof blocks and other material on the roof.** This was done as far as possible through remote operation, using the machinery developed in 1 and 2 shown before.



▲ Roof of the lower section
(before improvement)

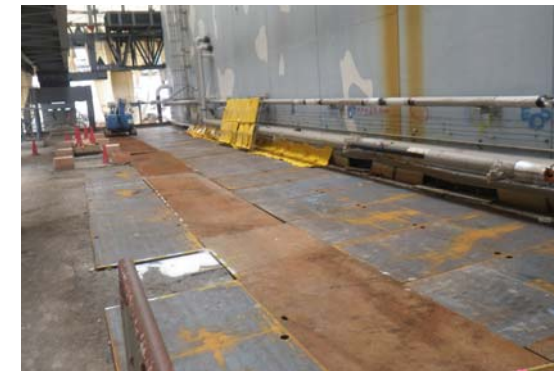


▲ Removal using small grippers



▲ Suction using rubble suction machine

**Solution to [Problem (2)]
= Improve environment**



▲ Roof of the lower section
(after improvement)

Removed small rubble pieces and roof blocks, laid steel plate, and installed lead plate

3. Measures to reduce exposure in each type of work

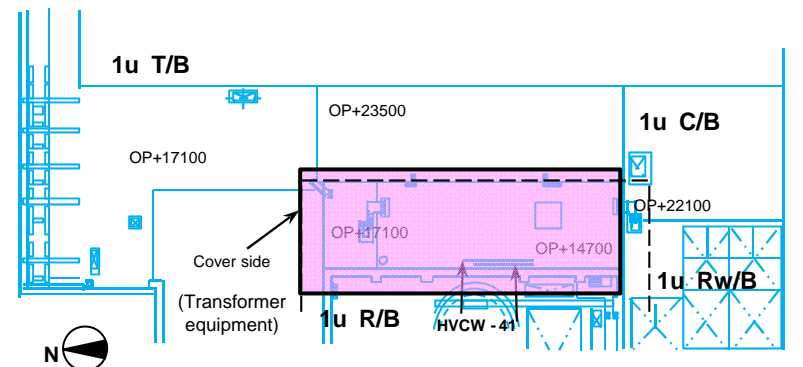
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3') Results of improving atmospheric dose on roof of lower section on east side

(24 points)

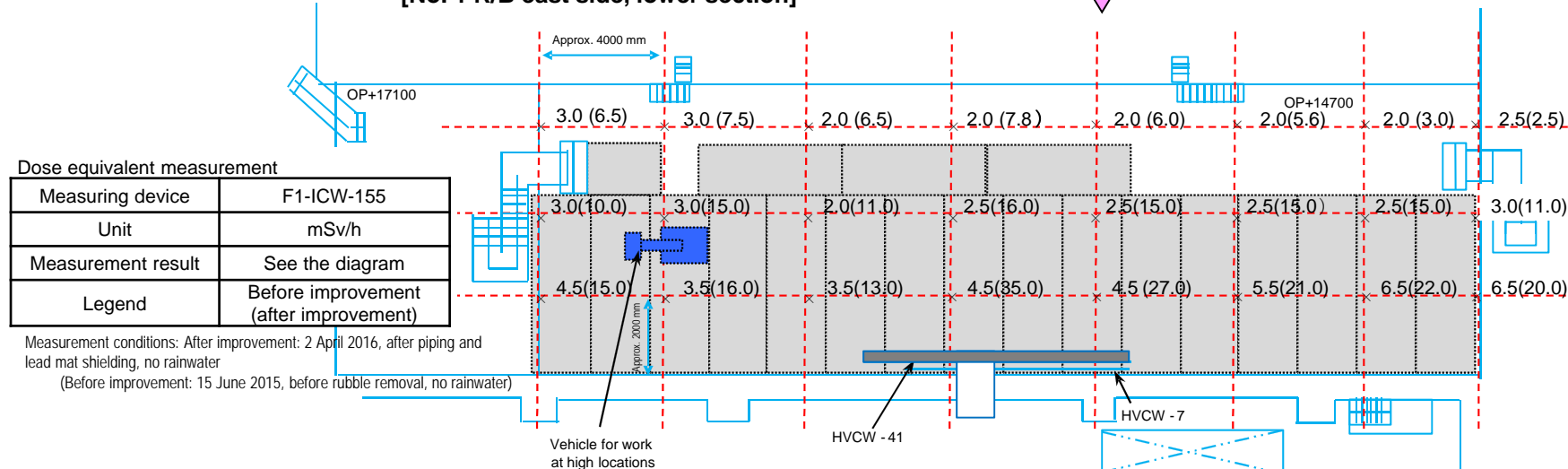
Measurement date	15 Apr 2015	2 Apr 2016
Measurement condition	Before improvement (Before rubble removal)	After improvement (After shielding with lead mat)
Geometric mean value	11.24 mSv/h	3.04 mSv/h

Comparison conditions	Before improvement/after improvement
Percentage reduction	73.0% reduction



 : Steel plate laid
 : Lead mat

[No. 1 R/B east side, lower section]



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4. Implementations afterwards

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4) Suction of rubble pieces such as roof blocks on operation floor using the large rubble suction system "Karuwaza-2"

Prior to dismantling of the building cover wall panels, a plan was adopted of suctioning up small loose rubble pieces such as roof blocks on the operation floor in order to reduce, even a little, the risk of scattering radioactive dust.

In order to efficiently remove small rubble pieces over a wide area, a large rubble suction system was developed, and all guidance and operation were performed remotely.



▲ Obstacle removal using small grippers (moving)



▲ Suction of rubble pieces such as roof blocks using large rubble suction machine



▲ Discharge of small rubble pieces using the large rubble suction machine

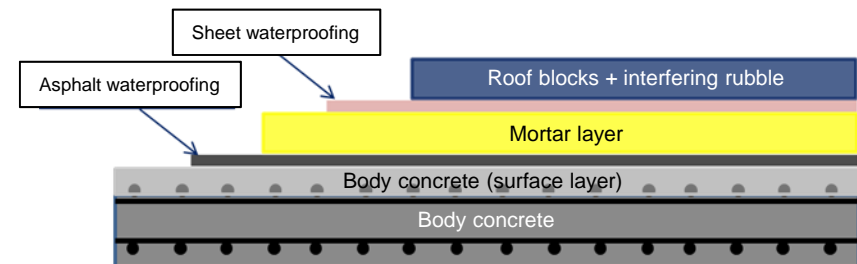
4. Implementations afterwards

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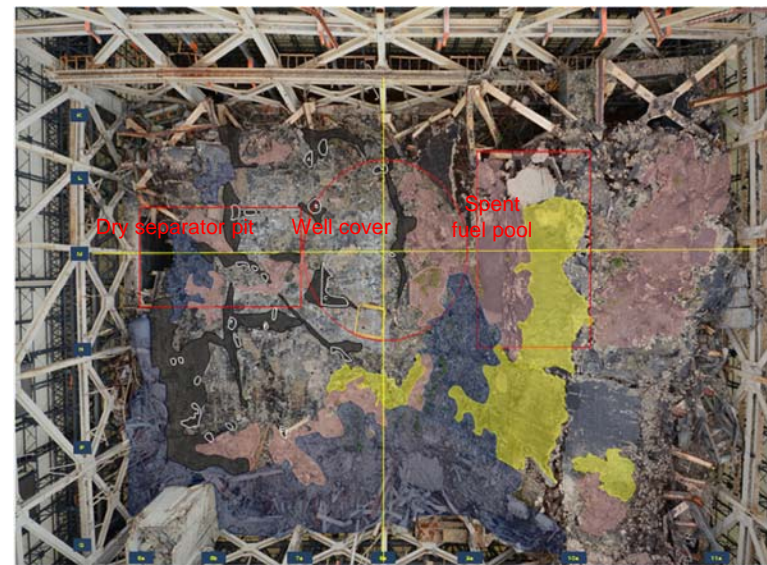
4') Results of suctioning rubble such as roof blocks on operation floor

Results compared to a total planned suction amount of approx. 90 m³ were: approx. 70 m³ suctioned (about 76%). Dosimetry values in rubble containers (holding 1–3m³ of rubble) were 4–70 mSv/h (geometric mean of 15.3 mSv/h). (As of 3 August 2016)

Following dismantling of cover wall panels, suction work will continue while making adjustments between work steps.



▲ Before suctioning small rubble pieces



▲ After suctioning small rubble pieces (color-coded diagram)

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5. Radiation exposure levels of workers and effectiveness of measures to reduce exposure 14

For the work described before, **remote operation** and **environmental improvement** were priority items among measures for reducing exposure (◎ in the first table). However various other reduction measures were also taken (○ in the first table).

Measures to reduce radiation exposure Work item	Separation		Shielding				Removal of radiation sources	Work efficiency improvement		Management		
	Remote operation	Prevent work nearby when handling rubble containers	Set up shield in rubble storage area	Lay steel plate or set up lead mat, sandbags	Wear shielding vests	Set up shelter areas	Remove small rubble pieces, roof blocks, etc.	Save labor on-site through unit integration	Training using mockups (off-site)	Hold meetings consistently before work, disseminate on-site dose rates	Raise awareness by posting on-site doses	Manage time and limit daily dose (prevent excessive exposure)
1) Small rubble suction	◎	○	○		○	○			◎	○	○	○
2) Obstructing steel frame removal	◎	○	○		○	○			◎	○	○	○
3-1) Installation of nozzle unit steel frame	◎				○	○		○	○	○	○	○
3-2) Rooftop work for mist pipes, etc.	◎	○	○	◎	○	○	◎	○		○	○	○

The second table compares the results of these efforts (◎ + ○ in the first table) and estimates for the case of limited measures (only ○ in the first table).

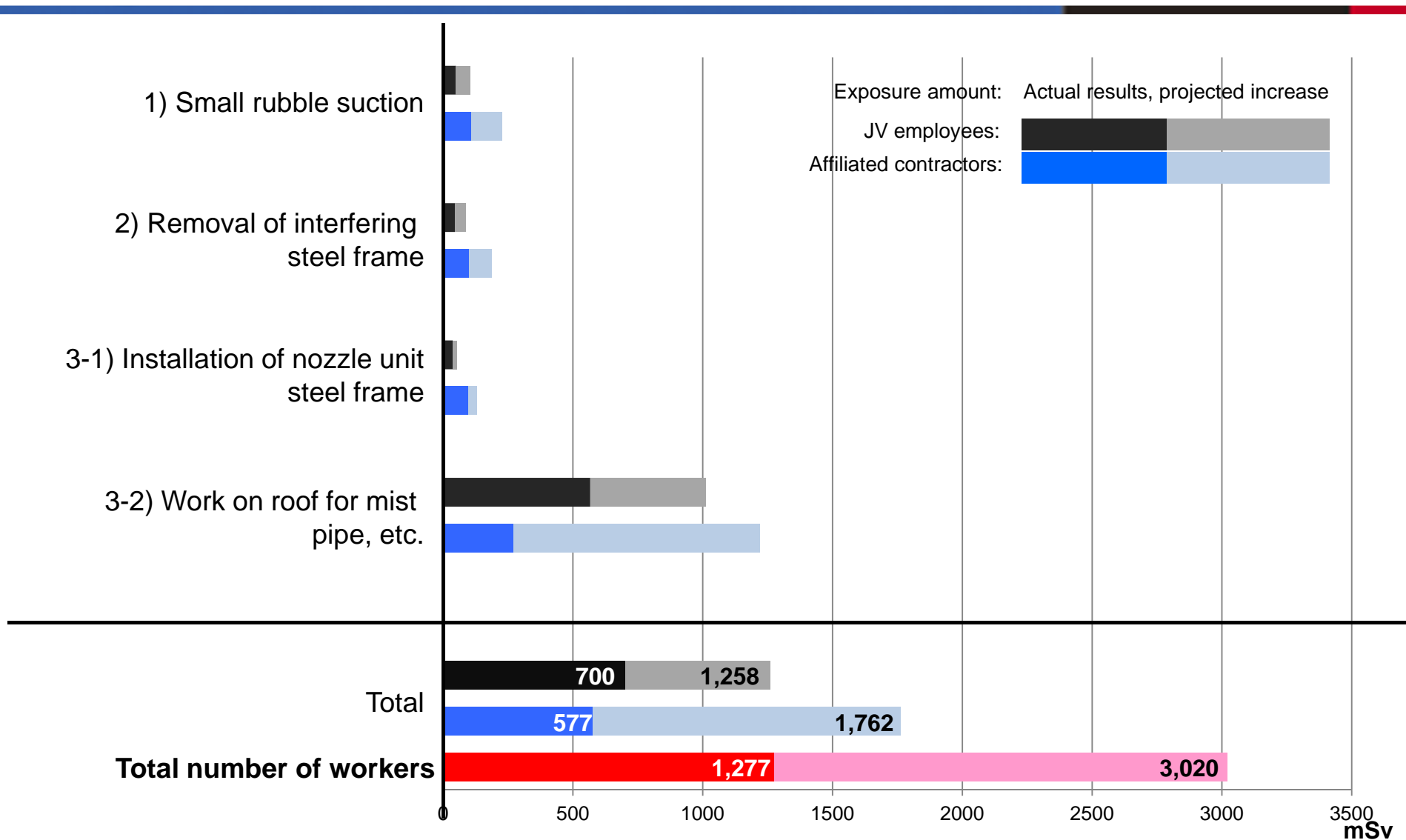
Work item	Number of operators and exposure doses	Actual results this time		Projected increase in case of limited measures		Projected total in the case of limited measures		Percentage reduction	
		(a)		(b)		(c)=(a)+(b)		(d)=(b)/(c)	
		Number of operators (Person-days)	Total exposure (mSv)	Number of operators (Person-days)	Total exposure (mSv)	Number of operators (Person-days)	Total exposure (mSv)	Number of operators (%)	Total exposure (%)
1) Small rubble suction	JV employees	277	49.80	114	56.44	391	106.24	29.2%	53.1%
	Affiliated contractors	735	108.70	386	119.39	1,121	228.09	34.4%	52.3%
2) Obstructing steel frame removal	JV employees	255	46.30	80	41.09	335	87.39	24.0%	47.0%
	Affiliated contractors	1,030	99.40	273	86.63	1,303	186.03	20.9%	46.6%
3-1) Installation of nozzle unit steel frame	JV employees	153	37.65	36	16.64	189	54.29	18.9%	30.7%
	Affiliated contractors	545	97.30	107	31.55	652	128.85	16.5%	24.5%
3-2) Rooftop work for mist pipes, etc.	JV employees	1,274	566.90	776	443.92	2,050	1,010.82	37.8%	43.9%
	Affiliated contractors	519	271.65	1,476	947.62	1,995	1,219.27	74.0%	77.7%
Total	JV employees	1,959	700.65	1,006	558.10	2,965	1,258.75	33.9%	44.3%
	Affiliated contractors	2,829	577.05	2,242	1,185.19	5,071	1,762.24	44.2%	67.3%
(All workers)	Grand total	4,788	1,277.70	3,248	1,743.29	8,036	3,020.99	40.4%	57.7%

* 1 person-day is 1 person working 2–4 h in 1 day

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5. Radiation exposure levels of workers and effectiveness of measures to reduce exposure

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Actual dose was reduced by approx. 57% compared to the projected dose when using limited measures only.

<Reference> (1) Specifications of "Karuwaza-1" and "Karuwaza-2" 16

Item	[Karuwaza-1]	[Karuwaza-2]
Appearance		
Material to be recovered	<ul style="list-style-type: none"> Concrete rubble pieces on perimeter steel frame (approx. 20 kg max.) High dose rubble pieces in dust form 	<ul style="list-style-type: none"> Roof blocks (approx. 3.5 kg, 200 x 400 x t30 mm) Concrete rubble pieces (approx. 40 kg max.) River sand for water proofing
Main specifications	<ul style="list-style-type: none"> Operation method: Suspended from crane and operated remotely Approximate dimensions of main body (not including hand railing), weight: L13 x W2.5 x H5.5 m, 22 t Suction air flow rate: 360 m³/min (adjustable air flow rate) Suction air speed: up to 100 m/s Filter configuration <ul style="list-style-type: none"> Rubble trap section (rubble pieces several mm or larger) HEPA filter (99.97% or higher) x 6 sheets x 2 levels Rubble bucket capacity: 1.5 m³ (disposable) Operating range of suction duct: Rotate ± 90°, extend/contract 1 m <div style="border: 2px solid red; padding: 5px; color: red; text-align: center; font-weight: bold;"> Recovery capacity: 1–2 m³/day (4 h work) </div>	<ul style="list-style-type: none"> Operation method: Suspended from crane and operated remotely Approximate dimensions of main body (not including hand railing), weight: L10 x W2.9 x H6.6 m, 35 t Suction air flow rate: 630 m³/min (adjustable air flow rate) Suction air speed: up to 65 m/s Filter configuration <ul style="list-style-type: none"> Rubble trap section (rubble pieces several mm or larger) Backwash type bag filter (99% or higher) HEPA filter (99.97% or higher) x 9 sheets Rubble bucket capacity: 2 m³ (with shielding t=22 mm) Operating range of suction duct: Rotate ± 90° <div style="border: 2px solid red; padding: 5px; color: red; text-align: center; font-weight: bold;"> Recovery capacity 3–4 m³/day (4 h work) </div>

Small steel frame
cutter/grippers
"Hitokuchi"



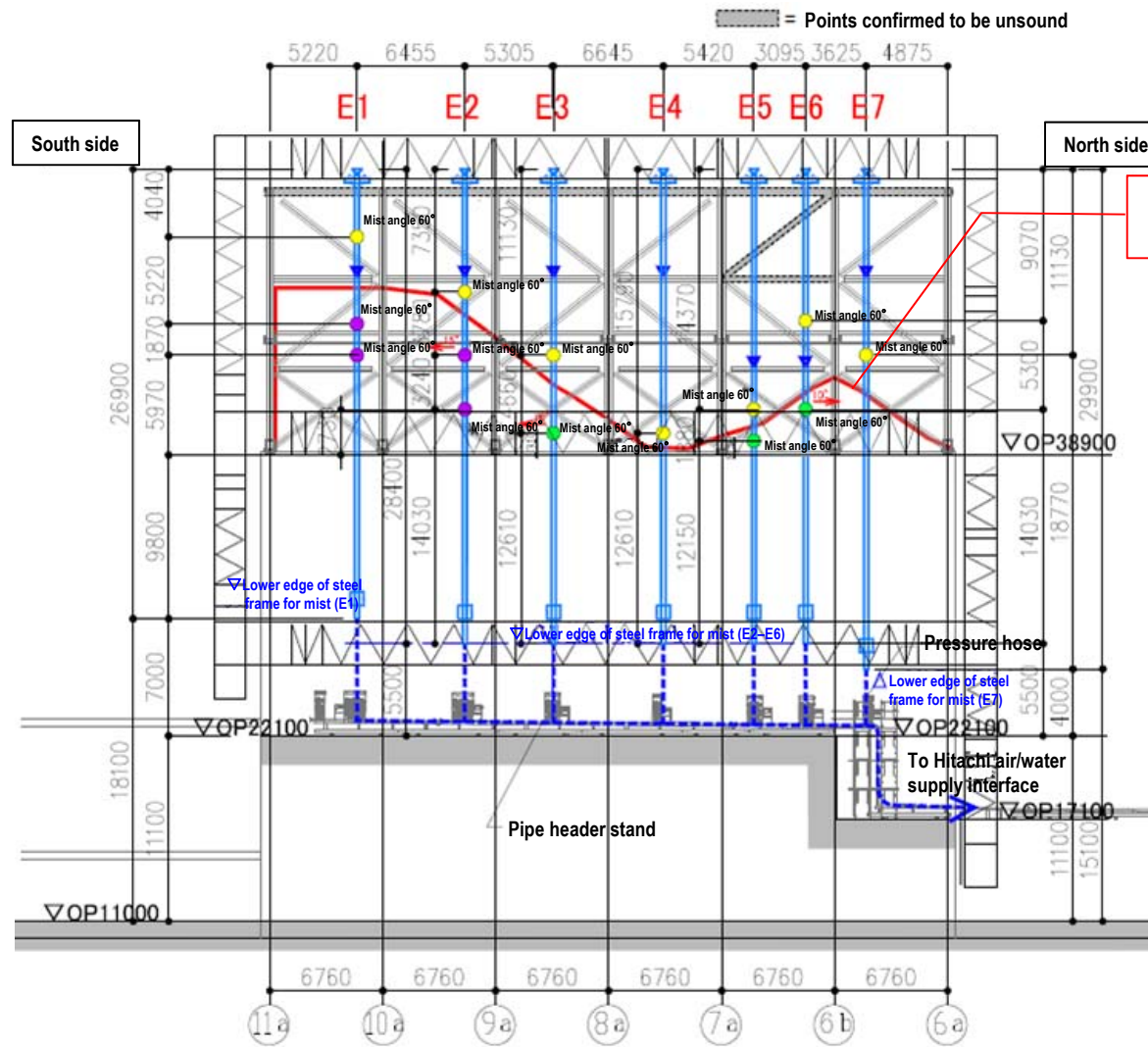
- Operating weight: 18 t
(including attachment weight)
- Power: Diesel engine 22 kW
- Installed power
 - (1) Hydraulic pump 21 MPa
 - (2) Hydraulic motor 25 MPa x 2 (fan rotation)
 - (3) Generator for survey equipment:
AC100 V, 3.1 kVA
- Attachments
 - (1) Cutter FE-350 x 1 (0.85 t)
 - (2) Grippers FE-350-PC x 1 (1.13 t)
- Network cameras
 - (1) WV-SC385 x 1
 - (2) AXIS M3027 x 2
 - (3) AXIS M5014 x 3
 - (4) Equipped with sound-focusing microphone

Suspended
type

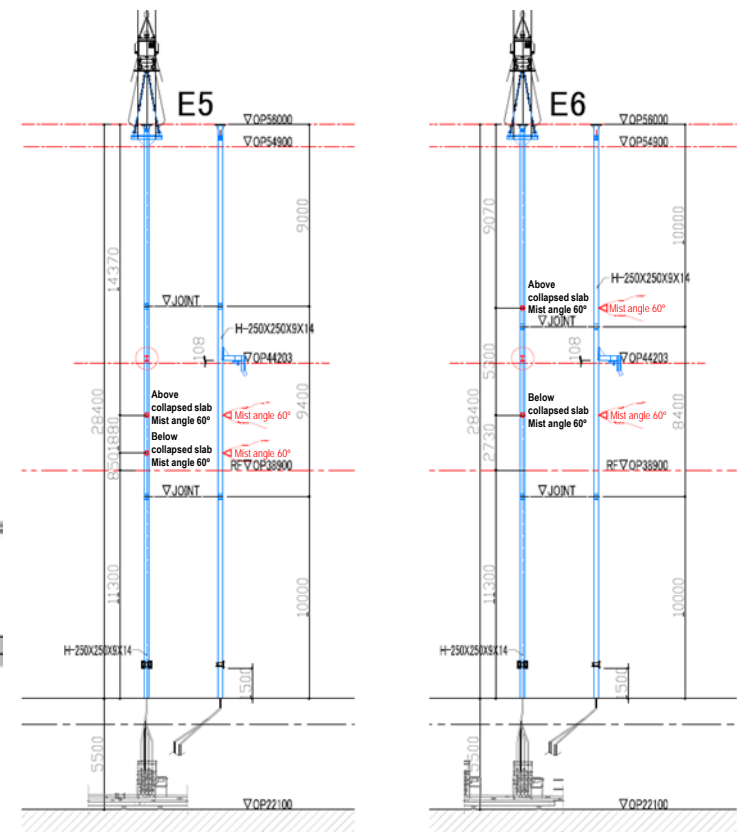
<Reference>

(3) Specifications of nozzle unit steel frame of mist spraying equipment

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▲ Layout (east side)



▲ Details of nozzle unit steel frames (example)



Thank you for your attention.