Overview of the Multi-nuclide Removal Equipment (ALPS) at Fukushima Daiichi Nuclear Power Station

March 29, 2013
Tokyo Electric Power Company

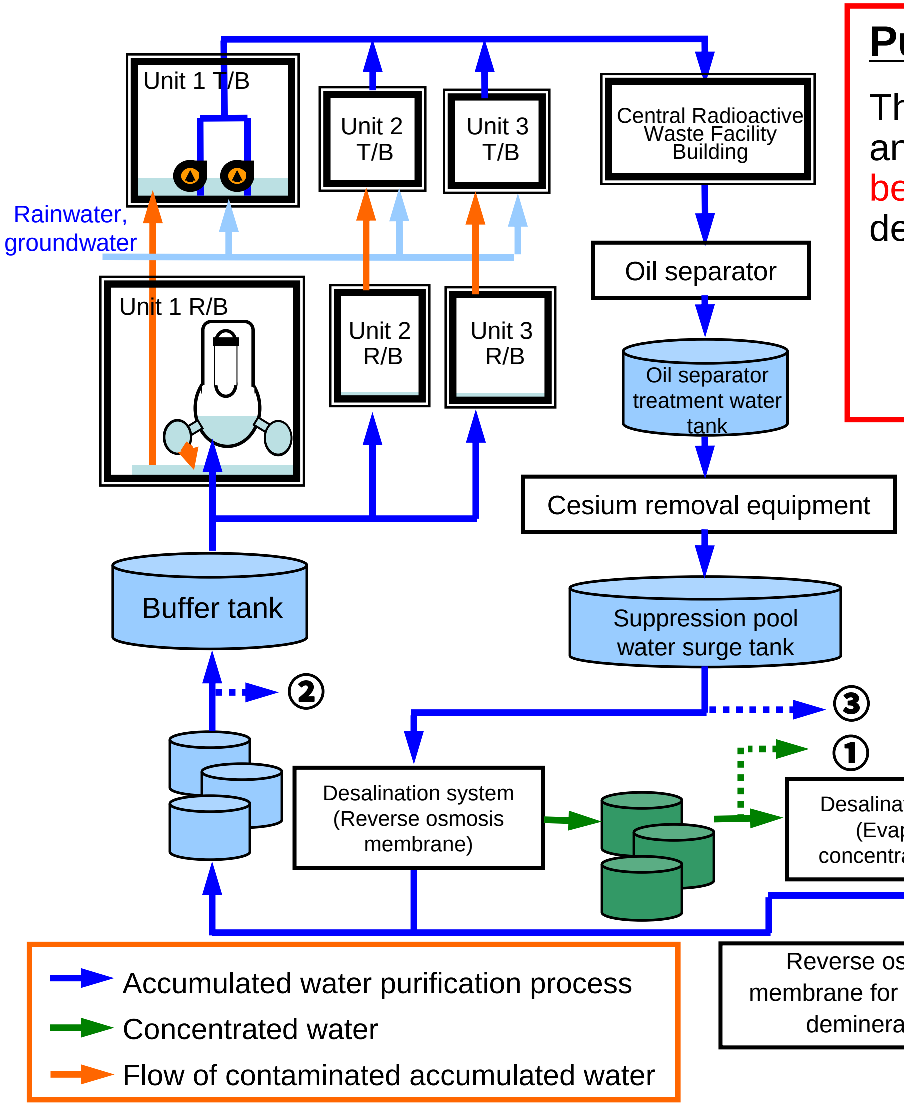
Purpose of Installing the Multi-nuclide Removal Equipment

Installation of the multi-nuclide removal equipment

Purpose

The existing water treatment facility removes mainly cesium and the densities of other radioactive nuclides also need to be reduced in order to further reduce the radioactivity density of treated water.

Introduction of the "multi-nuclide removal equipment"



Unit 1 T/B

Unit 2 T/B

Unit 3 T/B

Central Radioactive Waste Facility Building

Rainwater, groundwater

Unit 1 R/B

Unit 2 R/B

Unit 3 R/B

Oil separator

Oil separator treatment water tank

Cesium removal equipment

Buffer tank

Suppression pool water surge tank

②

③

①

Desalination system (Reverse osmosis membrane)

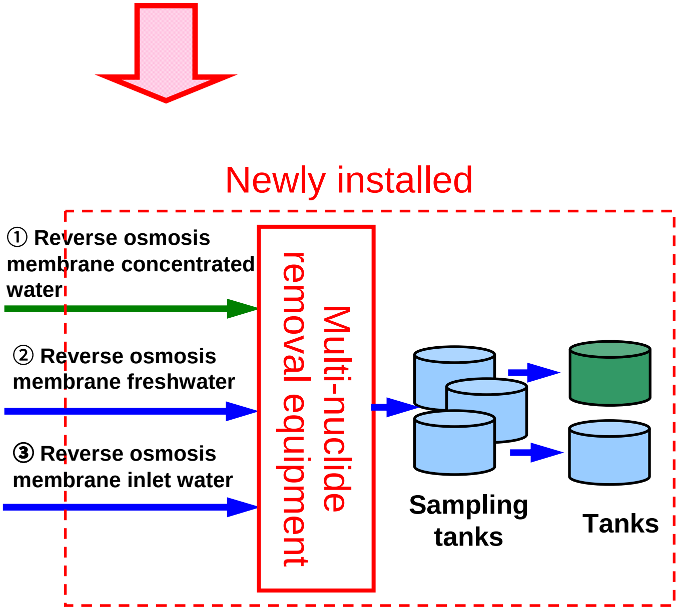
Desalination system (Evaporative concentration drums)

Reverse osmosis membrane for desalting, demineralizer

→ Accumulated water purification process

→ Concentrated water

→ Flow of contaminated accumulated water



Newly installed

① Reverse osmosis membrane concentrated water

② Reverse osmosis membrane freshwater

③ Reverse osmosis membrane inlet water

Multi-nuclide removal equipment

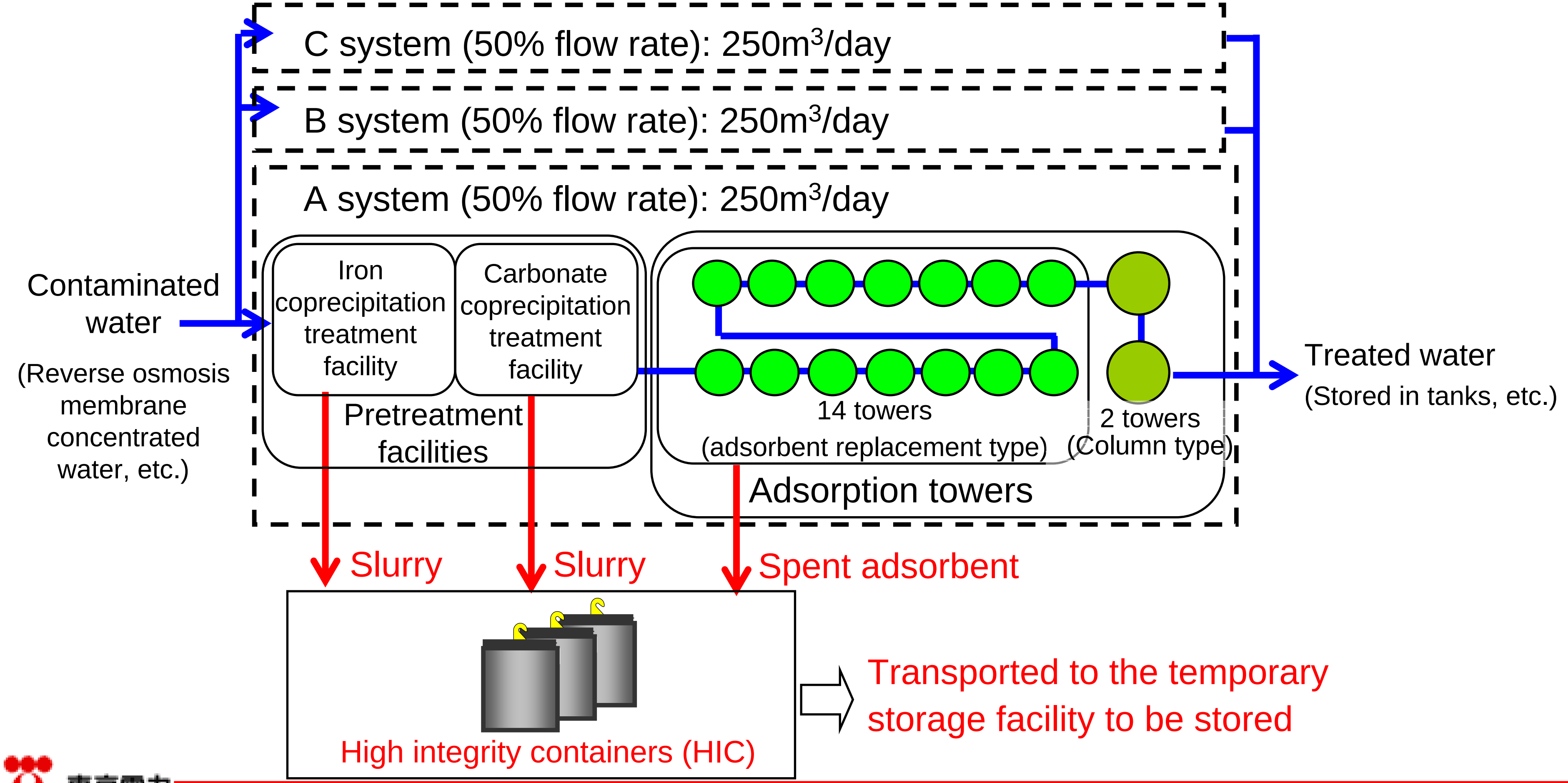
Sampling tanks

Tanks

Overview of the Multi-nuclide Removal Equipment

- Radioactive materials are removed by passing radioactive contaminated water through the pretreatment facilities and adsorption towers.

- The waste materials (slurry, spent adsorbent) are transferred into high integrity containers (HIC). HICs which store a specified amount of waste are transported to the temporary storage facility to be stored.



Current Status (1/2)

Progress of building construction for the multi-nuclide removal equipment
(Photos taken on March 27, 2013)

Photo taken from the south side

Photo taken from the northeast side

Photo taken from the north side

Current Status (2/2)

Progress of multi-nuclide removal equipment installation
(Photo taken on September 16, 2012)

Adsorption tower (Treatment column)
(Photo taken on March 27, 2013)

Control panels (Photos taken on March 27, 2013)

Hot Testing

- At hot testing, the capabilities of the multi-nuclide removal equipment to “remove radioactive materials” and to “maintain its capability to remove radioactive materials while in operation” are evaluated.

- In accordance with a direction given by NISA (at the time) “perform testing in a minimum amount of time/scope to evaluate the specified capabilities”, the hot testing will be performed on system A first.

[Evaluation of capability to remove radioactive materials]

- Confirm that the radioactivity densities of target 62 nuclides are below the density limit specified by the Reactor Regulation.

- Perform evaluation during the period in which approx. 1000-2000m^3 of water is treated per system.

[Evaluation of capability to maintain its capability to remove radioactive materials while in operation]

- Confirm that the capability to remove radioactive materials is maintained until the timing of adsorbent replacement.

- Considering that the longest adsorbent replacement cycle (adsorbent 7) is 121 days (Flow rate of treated water: approx. 30,000m^3), perform evaluation during the period in which approx. 30,000m^3 of water is treated per system.

Schedule for the Hot Testing and Full-scale Operation Commencement (1/2)

March 19: Approval given from the Nuclear Regulation Authority for starting hot testing of system A

March 25: Approval of change of the Technical specification for nuclear reactor facility related to hot testing

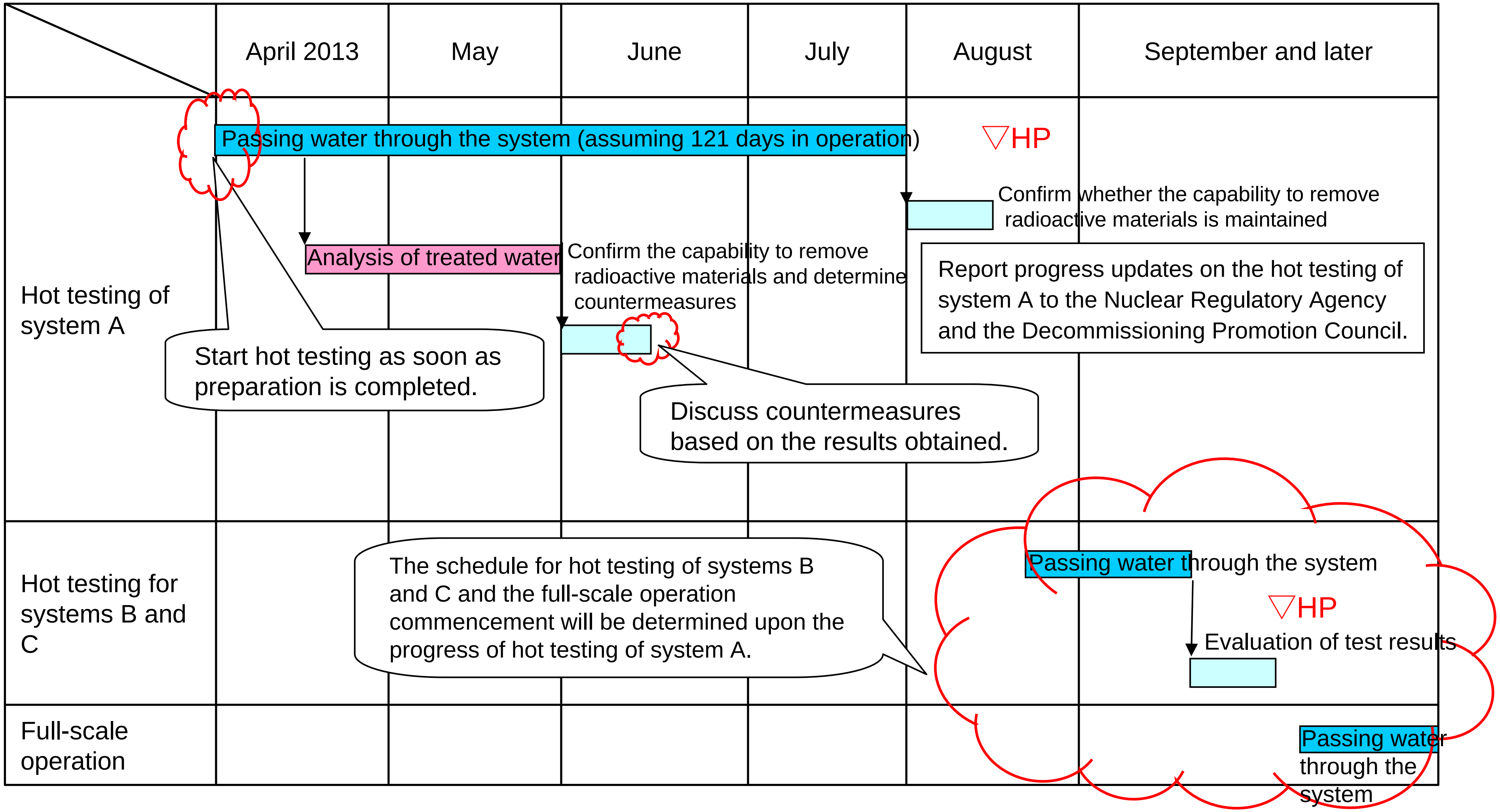
Hot testing is to be performed on system A first. The capabilities of the multi-nuclide removal equipment to remove radioactive materials and to maintain its capability to remove radioactive materials during the hot testing are evaluated.

The progress updates on the hot testing of system A will be reported to the Nuclear Regulatory Agency and the Decommissioning Promotion Council.

The schedule for hot testing of systems B and C and the full-scale operation commencement will be determined upon the progress of hot testing of system A.

Schedule for the Hot Testing and Full-scale Operation Commencement (2/2)

Schedule (Draft)



	April 2013	May	June	July	August	September and later
Hot testing of system A	Passing water through the system (assuming 121 days in operation) Start hot testing as soon as preparation is completed.	Analysis of treated water	Confirm the capability to remove radioactive materials and determine countermeasures Discuss countermeasures based on the results obtained.		▽HP Confirm whether the capability to remove radioactive materials is maintained Report progress updates on the hot testing of system A to the Nuclear Regulatory Agency and the Decommissioning Promotion Council.	
Hot testing for systems B and C		The schedule for hot testing of systems B and C and the full-scale operation commencement will be determined upon the progress of hot testing of system A.			Passing water through the system	▽HP Evaluation of test results
Full-scale operation						Passing water through the system

HP: Hold point

Evaluation of Risks Accompanying the Operation of the Multi-nuclide Removal Equipment (1/4)

Appropriate measures against the risks accompanying the operation of the multi-nuclide removal equipment (leakage, radiation exposure, etc.) have been implemented.

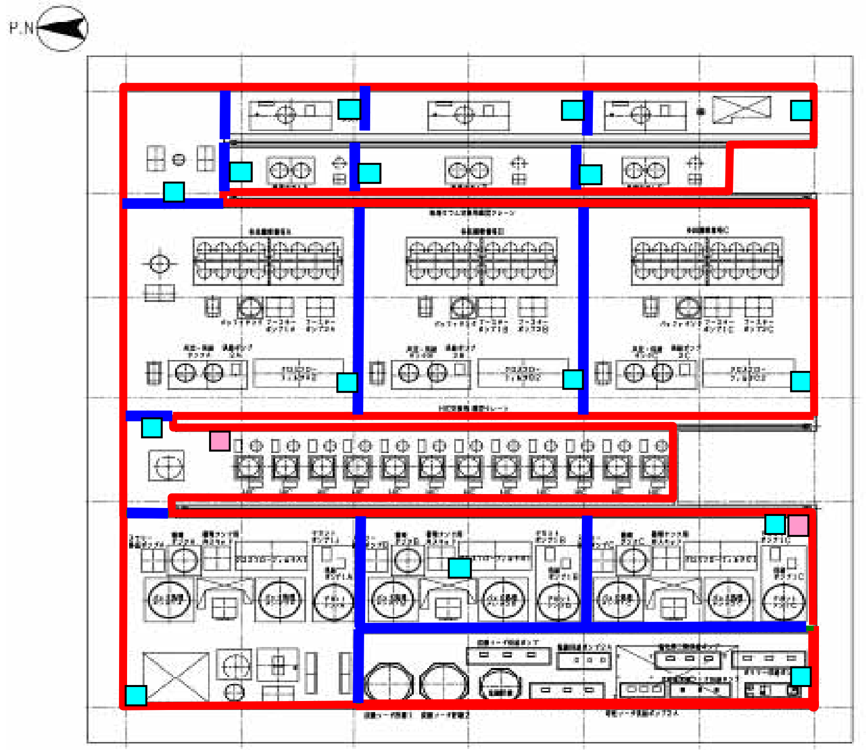
Measures against risk of leakage

Risks		Measures
Internal	Aged deterioration	- Ensure proper operation and maintenance - Install covering materials (including insulation materials) on the pipes, install UV protective cover on polyethylene pipes - Long-term soundness of HIC during the storage period (20 years) has been confirmed
	Accident	- Ensure proper operation and maintenance - Ensure the soundness of HIC by implementing reinforcements in consideration of possibility to drop during handling, Implement measures to prevent HICs from dropping
	Human error	Create a procedure manual, provide education and training, implement measures against human errors
External	Freezing	Install insulation materials on the pipes and pumps, remove water from the pipes and pumps
	Earthquake	- Prevent leakage by building a dam or embankment. Perform patrol inspection to monitor conditions - Use polyethylene or stainless-steel pipes with a low risk of leakage
	Tsunami	- Equipment is installed on the hill to prevent Tsunami damage
	Fire	- Efforts in early stage fire detection, install firefighting equipment - Perform patrol every day for early detection of fire and other abnormalities
	Typhoon, tornado	- Prevent leakage by building a dam or embankment. Perform patrol inspection to monitor conditions - Use polyethylene or stainless-steel pipes with a low risk of leakage
	Man-made incident	- Prevent leakage by building a dam or embankment. Perform patrol inspection to monitor conditions - Use polyethylene or stainless-steel pipes with a low risk of leakage

Evaluation of Risks Accompanying the Operation of the Multi-nuclide Removal Equipment (2/4)

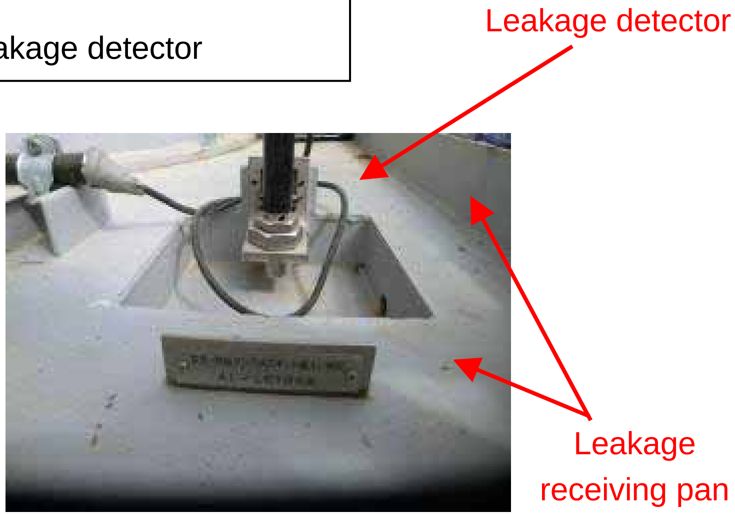
Leakage expansion prevention measures (Multi-nuclide removal equipment)

- Install a leakage receiving pan and leakage detector on each equipment skid comprising the facility.
- Build a system separation dam (height: 100mm-300mm) and a dam along the outer circumference (height: 500mm) to prevent leakage from expanding to the outside of the multi-nuclide removal equipment area.
- Install a floor leakage detector in each area segregated by dam in order to allow for leakage detection when leakage occurs outside of the skid.
- Continue monitoring utilizing cameras or area radiation monitors.



Leakage expansion prevention measures in the multi-nuclide removal equipment area

━ : Dam (Height: 500mm)
━ : Dam (Height: 100-300mm)
■ : Area radiation monitor
■ : Floor leakage detector



(Example) Leakage detector installed in the equipment skid

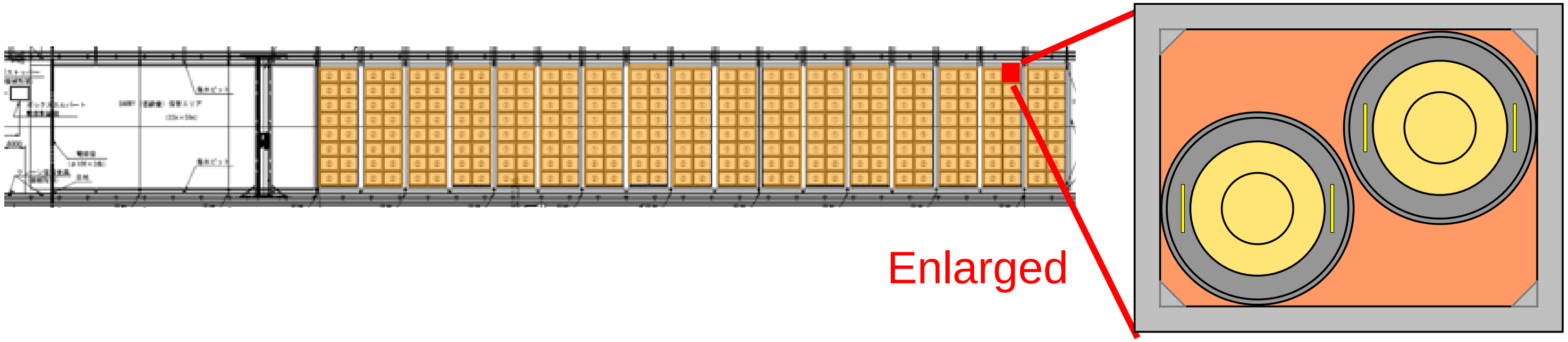
Evaluation of Risks Accompanying the Operation of the Multi-nuclide Removal Equipment (3/4)

Measures to prevent expansion of leakage (Temporary storage facility)

The high integrity containers (HIC) which store waste generated in the multi-nuclide removal equipment are transported to the spent cesium absorption tower temporary storage facility (the secondary facility) (hereafter the “temporary storage facility”) to be stored in the box culverts in the facility (See below). HICs with sufficient corrosion resistance and radiation resistance for long-term storage can be safely stored in the concrete box culverts. However, the following additional measure will be implemented to further enhance safety.

- Open the upper lid of the box culverts on a regular basis to check for leakage from the HICs. In the case of leakage from HIC, the leaked waste will remain inside the box culvert (See below).

*The regular leakage check is done on a representative HIC (the first one to be stored in the temporary storage facility which stores slurry of the highest radiation dose (iron coprecipitation treatment)) for the purpose of mitigating the radiation exposure among workers.



HIC storage in the temporary storage facility

Evaluation of Risks Accompanying the Operation of the Multi-nuclide Removal Equipment (4/4)

Measures to mitigate radiation exposure among workers

[Equipment design]

- ✓ The multi-nuclide removal equipment is designed so that the radiation dose is maintained at 1mSv/h or less at 1m from other equipment.
- ✓ The equipment can be remotely operated and monitored from the Control Room.
- ✓ The Control Room is located at approx. 900m from the multi-nuclide removal equipment area and the radiation dose increase in the Control Room due to the operation of the equipment is estimated to be about 3 μ Sv per year.
- ✓ A flushing line has been installed for the purpose of mitigating radiation exposure at the time of equipment maintenance.

[Radiation protection]

- ✓ Inform workers on the multi-nuclide removal equipment area and install signs to prevent unnecessary entry into the area by those other than radiation workers in charge of equipment operation.
- ✓ Install signs in areas of high radiation doses in order to mitigate radiation exposure among radiation workers in charge of equipment operation.

[Individual radiation exposure control]

- ✓ As the area is estimated to have high β ray dose rates due to a large amount of β nuclides included in the treated water, the following radiation dose control measure will be implemented.
  - Require workers to put on appropriate dosimeter (for example, a β ray dosimeter and ring badge for workers exposed to β ray) in consideration of radiation source and encourage them to measure the dose rates regularly.

(Reference) Removal of Radioactive Materials Through the Operation of the Multi-nuclide Removal Equipment (1/5)

Comparison of radioactivity densities between contaminated water and water treated by the multi-nuclide removal equipment and the ratio of radioactivity densities to the density limit specified by the Reactor Regulation*

	Nuclide (Approx. half life)	① Density limit specified by the Reactor Regulation (The density limit in the water outside the surrounding monitored areas provided in section 6 of Appendix 2) [Bq/cm^3]	Contaminated water (RO concentrated water)		Water treated by the multi-nuclide removal equipment	
			② Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation②/①	③ Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation ③/①
1	Rb-86 (19 days)	4E-01	N.D. < 6.1E+00	1.5E+01	N.D. < 1.3E-03	3.3E-03
2	Sr-89 (51 days)	3E-01	1.2E+04	4.0E+04	N.D. < 2.8E-04	9.3E-04
3	Sr-90 (29 years)	3E-02	1.1E+05	3.7E+06	N.D. < 9.7E-05	3.2E-03
4	Y-90 (64 hours)	3E-01	1.1E+05	3.7E+05	N.D. < 9.7E-05	3.2E-04
5	Y-91 (59 days)	3E-01	N.D. < 1.6E+02	5.3E+02	N.D. < 4.5E-02	1.5E-01
6	Nb-95 (35 days)	1E+00	N.D. < 7.2E-01	7.2E-01	N.D. < 1.3E-04	1.3E-04
7	Tc-99 (210000 years)	1E+00	6.8E-02	6.8E-02	N.D. < 5.4E-05	5.4E-05
8	Ru-103 (40 days)	1E+00	N.D. < 1.1E+00	1.1E+00	N.D. < 1.5E-04	1.5E-04
9	Ru-106 (370 days)	1E-01	3.0E+01	3.0E+02	N.D. < 1.2E-03	1.2E-02
10	Rh-103m (56 minutes)	2E+02	7.7E-01	3.9E-03	N.D. < 3.1E-05	1.5E-07
11	Rh-106 (30 seconds)	3E+02	3.0E+01	1.0E-01	N.D. < 1.2E-03	4.0E-06
12	Ag-110m (250 days)	3E-01	N.D. < 8.8E-01	2.9E+00	N.D. < 1.2E-04	4.0E-04
13	Cd-113m (15 years)	4E-02	N.D. < 3.3E-02	8.2E-01	N.D. < 4.5E-06	1.1E-04

*As for the nuclides whose densities are less than the detection limit (ND), the ratio of radioactivity density to the density limit specified by the Reactor Regulation is calculated based on the detection limit.

(Reference) Removal of Radioactive Materials Through the Operation of the Multi-nuclide Removal Equipment (2/5)

Comparison of radioactivity densities between contaminated water and water treated by the multi-nuclide removal equipment and the ratio of radioactivity densities to the density limit specified by the Reactor Regulation*

	Nuclide (Approx. half life)	① Density limit specified by the Reactor Regulation (The density limit in the water outside the surrounding monitored areas provided in section 6 of Appendix 2) [Bq/cm^3]	Contaminated water (RO concentrated water)		Water treated by the multi-nuclide removal equipment	
			② Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation②/①	③ Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation ③/①
14	Cd-115m (45 days)	3E-01	N.D. < 3.5E+01	1.2E+02	N.D. < 7.8E-03	2.6E-02
15	Sn-119m (290 days)	2E+00	N.D. < 1.2E+01	6.0E+00	N.D. < 2.8E-03	1.4E-03
16	Sn-123 (130 days)	4E-01	N.D. < 9.1E+01	2.3E+02	N.D. < 2.1E-02	5.3E-02
17	Sn-126 (100000 years)	2E-01	N.D. < 1.1E-01	5.5E-01	N.D. < 2.4E-05	1.2E-04
18	Sb-124 (60 days)	3E-01	N.D. < 5.7E-01	1.9E+00	N.D. < 2.1E-04	7.0E-04
19	Sb-125 (3 years)	8E-01	1.0E+02	1.3E+02	N.D. < 4.0E-04	5.0E-04
20	Te-123m (120 days)	6E-01	N.D. < 2.0E+00	3.3E+00	N.D. < 1.2E-04	2.0E-04
21	Te-125m (58 days)	9E-01	N.D. < 1.5E+02	1.7E+02	N.D. < 2.4E-02	2.7E-02
22	Te-127 (9 hours)	5E+00	N.D. < 1.1E+02	2.2E+01	N.D. < 1.7E-02	3.4E-03
23	Te-127m (110 days)	3E-01	N.D. < 1.1E+02	3.7E+02	N.D. < 2.4E-02	8.0E-02
24	Te-129 (70 minutes)	1E+01	N.D. < 1.8E+01	1.8E+00	N.D. < 1.1E-02	1.1E-03
25	Te-129m (34 days)	3E-01	N.D. < 2.5E+01	8.3E+01	N.D. < 3.8E-03	1.3E-02
26	I-129 (16000000 years)	9E-03	5.3E-01	5.9E+01	N.D. < 9.8E-04	1.1E-01

*As for the nuclides whose densities are less than the detection limit (ND), the ratio of radioactivity density to the density limit specified by the Reactor Regulation is calculated based on the detection limit.

(Reference) Removal of Radioactive Materials Through the Operation of the Multi-nuclide Removal Equipment (3/5)

Comparison of radioactivity densities between contaminated water and water treated by the multi-nuclide removal equipment and the ratio of radioactivity densities to the density limit specified by the Reactor Regulation*

	Nuclide (Approx. half life)	① Density limit specified by the Reactor Regulation (The density limit in the water outside the surrounding monitored areas provided in section 6 of Appendix 2) [Bq/cm³]	Contaminated water (RO concentrated water)		Water treated by the multi-nuclide removal equipment	
			② Radioactivity density [Bq/cm³]	Ratio to the density limit specified by the Reactor Regulation②/①	③ Radioactivity density [Bq/cm³]	Ratio to the density limit specified by the Reactor Regulation ③/①
27	Cs-134 (2 years)	6E-02	1.5E+01	2.5E+02	N.D. < 2.9E-04	4.8E-03
28	Cs-135 (3000000 years)	6E-01	N.D. < 5.5E+01	9.2E+01	N.D. < 9.7E-03	1.6E-02
29	Cs-136 (13 days)	3E-01	N.D. < 6.2E-01	2.1E+00	N.D. < 1.1E-04	3.7E-04
30	Cs-137 (30 years)	9E-02	2.0E+01	2.2E+02	N.D. < 3.6E-04	4.0E-03
31	Ba-137m (3 minutes)	8E+02	2.0E+01	2.5E-02	N.D. < 3.6E-04	4.5E-07
32	Ba-140 (13 days)	3E-01	N.D. < 3.7E+00	1.2E+01	N.D. < 5.0E-04	1.7E-03
33	Ce-141 (32 days)	1E+00	N.D. < 3.5E+00	3.5E+00	N.D. < 3.0E-04	3.0E-04
34	Ce-144 (280 days)	2E-01	N.D. < 1.6E+01	8.0E+01	N.D. < 9.2E-04	4.6E-03
35	Pr-144 (17 minutes)	2E+01	N.D. < 1.2E+02	6.0E+00	N.D. < 2.0E-01	1.0E-02
36	Pr-144m (7 minutes)	4E+01	N.D. < 1.4E+00	3.5E-02	N.D. < 2.4E-03	6.0E-05
37	Pm-146 (6 years)	9E-01	N.D. < 1.5E+00	1.7E+00	N.D. < 1.8E-04	2.0E-04
38	Pm-147 (3 years)	3E+00	N.D. < 8.5E+02	2.8E+02	N.D. < 6.9E-02	2.3E-02
39	Pm-148 (5 days)	3E-01	N.D. < 1.7E+00	5.7E+00	N.D. < 5.2E-04	1.7E-03

*As for the nuclides whose densities are less than the detection limit (ND), the ratio of radioactivity density to the density limit specified by the Reactor Regulation is calculated based on the detection limit.

(Reference) Removal of Radioactive Materials Through the Operation of the Multi-nuclide Removal Equipment (4/5)

Comparison of radioactivity densities between contaminated water and water treated by the multi-nuclide removal equipment and the ratio of radioactivity densities to the density limit specified by the Reactor Regulation*

	Nuclide (Approx. half life)	① Density limit specified by the Reactor Regulation (The density limit in the water outside the surrounding monitored areas provided in section 6 of Appendix 2) [Bq/cm^3]	Contaminated water (RO concentrated water)		Water treated by the multi-nuclide removal equipment	
			② Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation②/①	③ Radioactivity density [Bq/cm^3]	Ratio to the density limit specified by the Reactor Regulation ③/①
40	Pm-148m (41 days)	5E-01	N.D. < 1.6E+00	3.2E+00	N.D. < 1.3E-04	2.6E-04
41	Sm-151 (87 years)	8E+00	N.D. < 8.9E-02	1.1E-02	N.D. < 2.4E-05	3.0E-06
42	Eu-152 (13 years)	6E-01	N.D. < 7.0E+00	1.2E+01	N.D. < 5.1E-04	8.5E-04
43	Eu-154 (9 years)	4E-01	N.D. < 1.2E+00	3.0E+00	N.D. < 3.2E-04	8.0E-04
44	Eu-155 (5 years)	3E+00	N.D. < 8.7E-01	2.9E-01	N.D. < 2.3E-04	7.7E-05
45	Gd-153 (240 days)	3E+00	N.D. < 2.6E-01	8.7E-02	N.D. < 2.2E-07	7.4E-08
46	Tb-160 (72 days)	5E-01	N.D. < 2.0E+00	4.0E+00	N.D. < 3.7E-04	7.4E-04
47	Pu-238 (88 years)	4E-03	2.2E-03	5.5E-01	N.D. < 6.6E-05	1.7E-02
48	Pu-239 (24000 years)	4E-03	2.2E-03	5.5E-01	N.D. < 6.6E-05	1.7E-02
49	Pu-240 (6600 years)	4E-03	2.2E-03	5.5E-01	N.D. < 6.6E-05	1.7E-02
50	Pu-241 (14 years)	2E-01	9.7E-02	4.9E-01	N.D. < 2.9E-03	1.5E-02
51	Am-241 (430 years)	5E-03	2.2E-03	4.4E-01	N.D. < 6.6E-05	1.3E-02
52	Am-242m (150 years)	5E-03	2.2E-03	4.4E-01	N.D. < 6.6E-05	1.3E-02

*As for the nuclides whose densities are less than the detection limit (ND), the ratio of radioactivity density to the density limit specified by the Reactor Regulation is calculated based on the detection limit.

(Reference) Removal of Radioactive Materials Through the Operation of the Multi-nuclide Removal Equipment (5/5)

Comparison of radioactivity densities between contaminated water and water treated by the multi-nuclide removal equipment and the ratio of radioactivity densities to the density limit specified by the Reactor Regulation*

	Nuclide (Approx. half life)	① Density limit specified by the Reactor Regulation (The density limit in the water outside the surrounding monitored areas provided in section 6 of Appendix 2) [Bq/cm³]	Contaminated water (RO concentrated water)		Water treated by the multi-nuclide removal equipment	
			② Radioactivity density [Bq/cm³]	Ratio to the density limit specified by the Reactor Regulation②/①	③ Radioactivity density [Bq/cm³]	Ratio to the density limit specified by the Reactor Regulation ③/①
53	Am-243 (7400 years)	5E-03	2.2E-03	4.4E-01	N.D. < 6.6E-05	1.3E-02
54	Cm-242 (160 days)	6E-02	2.2E-03	3.7E-02	N.D. < 6.6E-05	1.1E-03
55	Cm-243 (29 years)	6E-03	2.2E-03	3.7E-01	N.D. < 6.6E-05	1.1E-02
56	Cm-244 (18 years)	7E-03	2.2E-03	3.1E-01	N.D. < 6.6E-05	9.5E-03
57	Mn-54 (310 days)	1E+00	1.1E+00	1.1E+00	N.D. < 1.1E-04	1.1E-04
58	Fe-59 (45 days)	4E-01	N.D. < 9.1E-01	2.3E+00	N.D. < 2.1E-04	5.3E-04
59	Co-58 (71 days)	1E+00	N.D. < 7.0E-01	7.0E-01	N.D. < 1.2E-04	1.2E-04
60	Co-60 (5 years)	2E-02	8.6E-01	4.3E+01	N.D. < 1.8E-04	9.0E-03
61	Ni-63 (100 years)	6E+00	4.3E+00	7.2E-01	N.D. < 1.2E-02	2.0E-03
62	Zn-65 (240 days)	2E-01	N.D. < 1.0E+00	5.0E+00	N.D. < 2.6E-04	1.3E-03

⇩

<u>Total sum of the ratio to the density limit (62 nuclides): 4.1E+06</u>

⇩

<u>Total sum of the ratio to the density limit (62 nuclides): 6.9E-01</u>

*As for the nuclides whose densities are less than the detection limit (ND), the ratio of radioactivity density to the density limit specified by the Reactor Regulation is calculated based on the detection limit.