Multi-nuclide Removal Equipment

Feb. 27, 2012

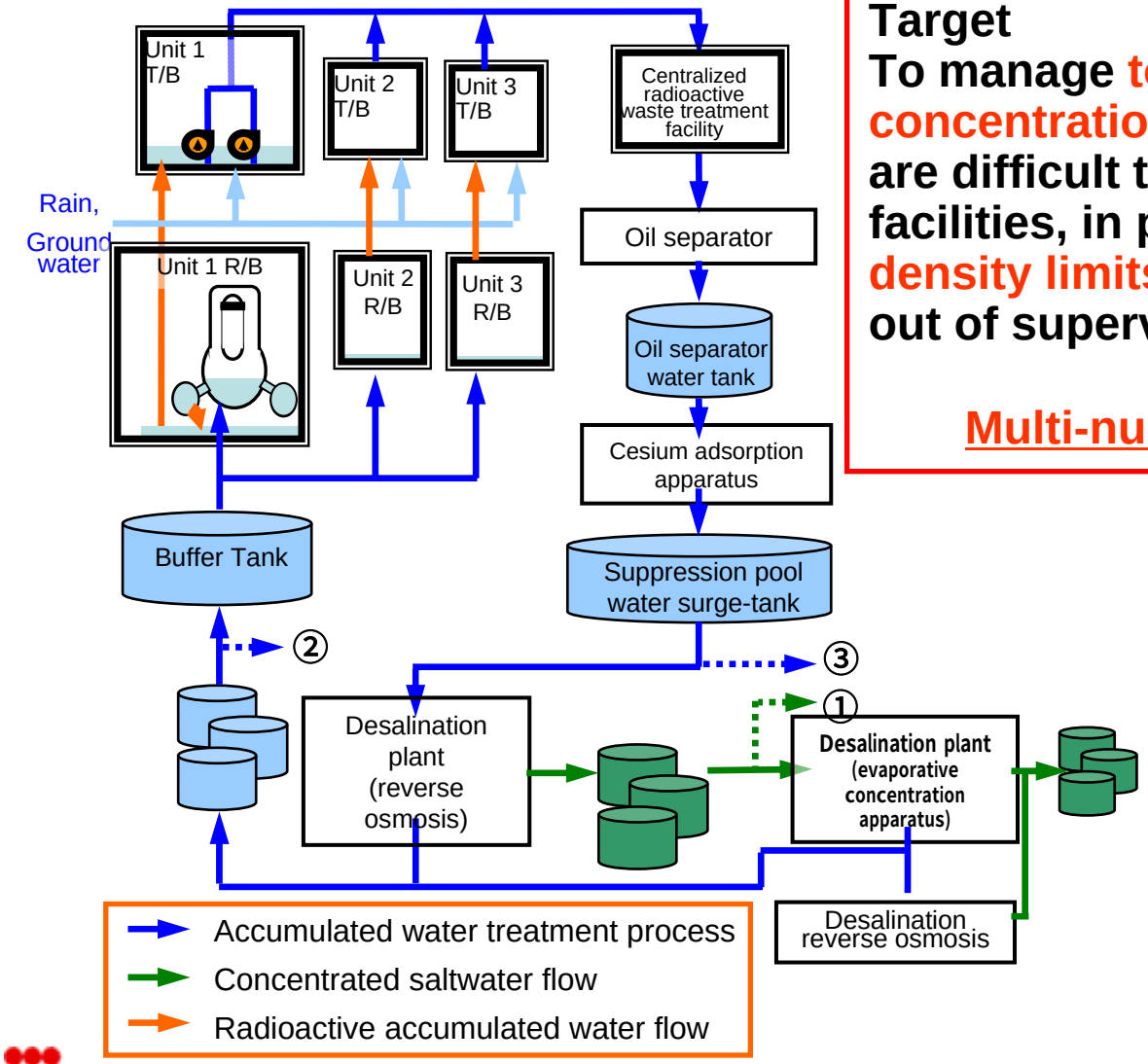
Tokyo Electric Power Company

TEPCO 東京電力

1. Installation of Multi-nuclide Removal Equipment

Excerpt from documents of Working Council on Jan. 23, 2012

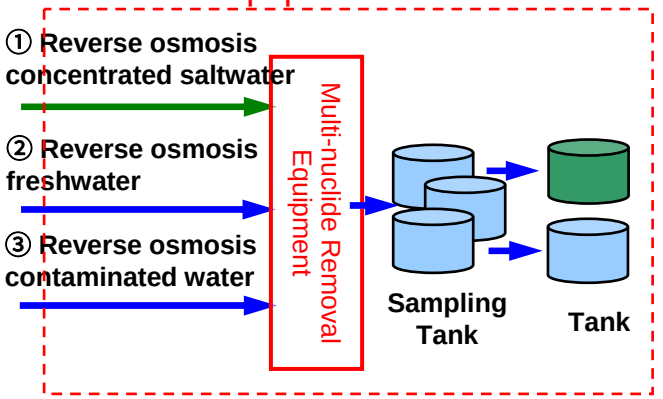
"Multi-nuclide Removal Equipment"



Target
To manage to keep radioactive substance concentrations other than Cesium, which are difficult to remove with the existing facilities, in processed water well below density limits by the announcement for out of supervised areas.

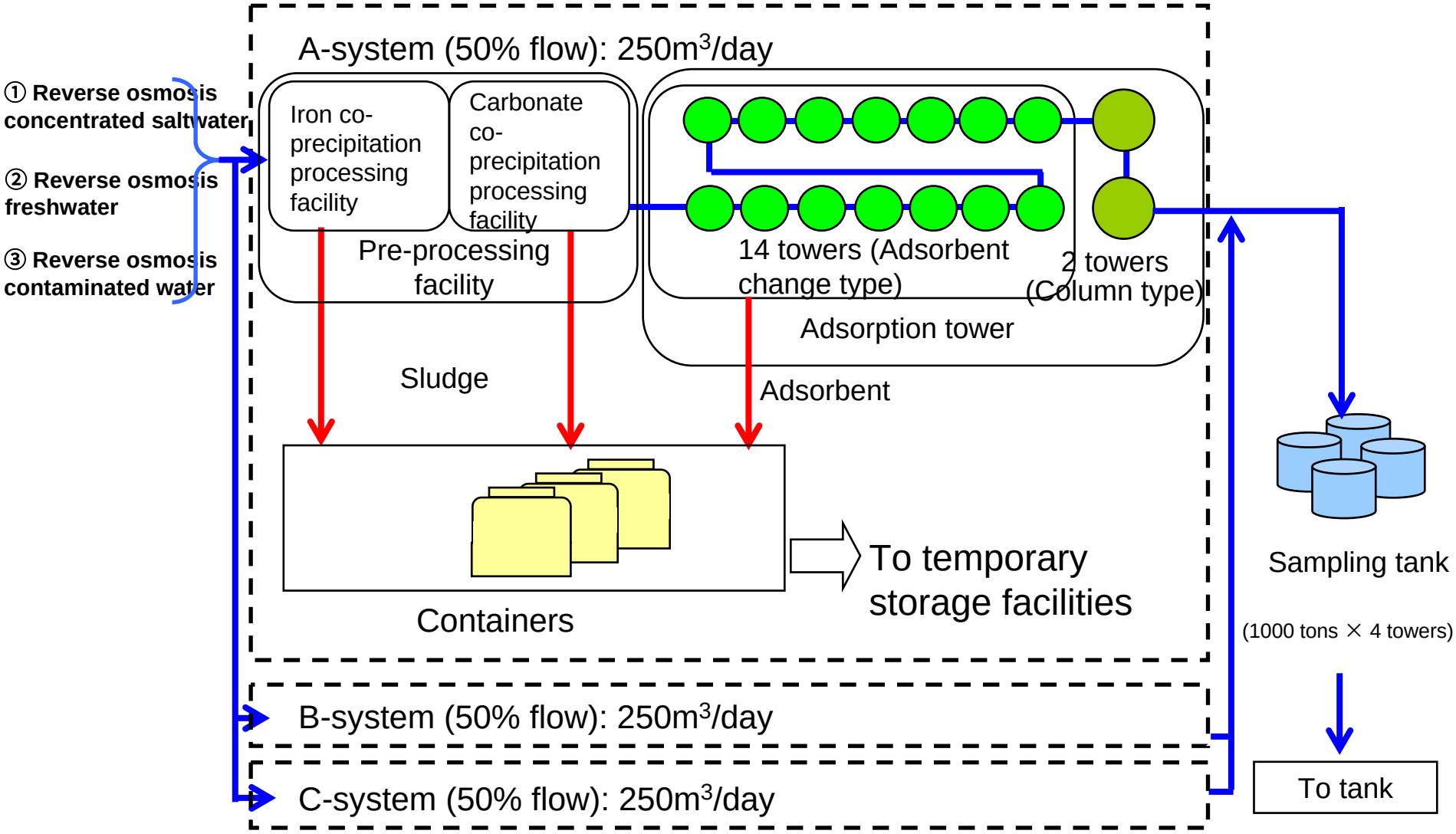
Multi-nuclide Removal Equipment

Equipment installation



2. Multi-nuclide Removal Equipment (ALPS) Outline

✓ALPS (Advanced Liquid Processing System)



2. Multi-nuclide Removal Equipment (ALPS) Outline

- System Structure
  - 50% two lines operation (500m^3/day)
  - One of two lines is suspended during changing adsorbent or on standby

- Main Facility Structure
  - Pre-processing facility
    - Iron co-precipitation processing facility
      - ✓ Removal of α nuclide, Co-60, Mn-54 etc.
    - Carbonate co-precipitation processing facility
      - ✓ Removal of adsorption blockade ion (Mg, Ca etc.)
  - Adsorption tower
    - ✓ Adsorption tower (adsorbent change type, column type): Removal of radioactive substances by each adsorbent (active carbon, artificial mineral, chelate resin etc.) according to each radioactive substances.
  - Waste storage container handling equipment
    - ✓ Crane
    - ✓ Waste transferring pumps and pipes

3. Results of Basic Test

Basic Test Results of Multi-nuclide Removal Equipment (1/2)

- The targets for this test were ① and ③, (①reverse osmosis concentrated saltwater, ② reverse osmosis freshwater and ③reverse osmosis contaminated water) which had high-radioactive concentration. (refer to ref. 4)
- Confirmed that γ nuclide could be removed below detection limit (not detected, ND) against targeted nuclide (45 nuclides).
- Confirmed that β nuclide could be purified to approx. 1/one-million~1/ten-million via gross β radiation measurement. Identifying nuclides with significant density for further purification (scheduled to complete measurement at the beginning of March)
  →After identifying nuclides, reflect on the removal plan.
- Based on the gross α radiation measurement, α nuclide could be cleaned till less than detection limit (ND). Analyzing each nuclide's density.

(Bq/L)

		Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater	
			Before process	After process	Before process	After process
γ nuclides	I-131 (approx. 8 days)	40	-	-	-	-
	Cs-134 (approx. 2 years)	60	4300	ND < 0.26	3400	ND < 0.27
	Cs-137 (approx. 30 years)	90	6100	ND < 0.30	ND < 460	ND < 0.32
	Mn-54 (approx. 310 days)	1000	14000	ND < 0.11	45000	ND < 0.12
	Co-58 (approx. 71 days)	1000	ND < 540	ND < 0.11	1200	ND < 0.12

3. Results of Basic Test

Basic Test Results of Multi-nuclide Removal Equipment (2/2)

(Bq/L)

		Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater	
			Before process	After process	Before process	After process
γ nuclides	Co-60 (approx. 5 years)	200	3900	ND < 0.16	14000	ND < 0.12
	Ru-103 (approx. 40 days)	1000	ND < 970	ND < 0.13	510	ND < 0.14
	Ru-106 (approx. 370 days)	100	ND < 7600	ND < 1.1	ND < 4700	ND < 1.1
	Sb-124 (approx. 60 days)	300	ND < 1800	ND < 0.27	ND < 1800	ND < 0.28
	Sb-125 (approx. 3 years)	800	63000	ND < 0.38	140000	ND < 0.37
	Ba-140 (approx. 13 days)	300	ND <3400	ND < 0.48	ND < 1700	ND < 0.51
	La-140 (approx. 40 hours)	400	-	-	-	-
Gross β			230000000	31	43000000	68
Gross α			16	ND < 0.066	0.46	ND < 0.066

※ ND: Below detection limit, <○○: Detection limit

※ ( ): Half-life

※ I-131 and La-140 are not target nuclides because they have not detected in recent accumulated water measurement.

4. Waste Storage Measures and Amount of Waste

Waste storage measures and amount of waste

Waste will be transferred into containers and stored in the temporary storage facilities in the site.

Waste	○Radioactive spent adsorbent ○Radioactive sludge
Storage measures	○Store in storage container with dewater ○Change an adsorbent with a column if changing opportunities are not frequent
Amount of containers	○Reverse osmosis contaminated water processing ・Storage container: approx. 0.5 containers/ day (approx. 180 containers/ year) ・Column type: approx. 0.04 containers/day (approx. 15 containers/ year) ○Reverse osmosis concentrated saltwater processing ・Storage container: approx. 1.3 containers/ day (approx. 470 containers/ year) ・Column type: approx. 0.04 containers/ day (approx. 15 containers/ year)
Container size	Diameter approx. 1.6 × height approx. 1.9m (cylindrical type)
Storage period	Approx. 20 years（Plan to carry on the R&D of disposal methods during this period. Storage container's life is evaluated to be over 20 years.

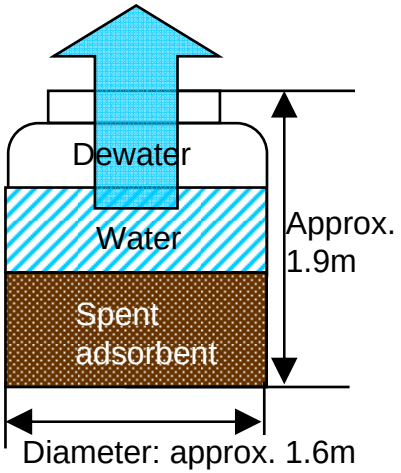
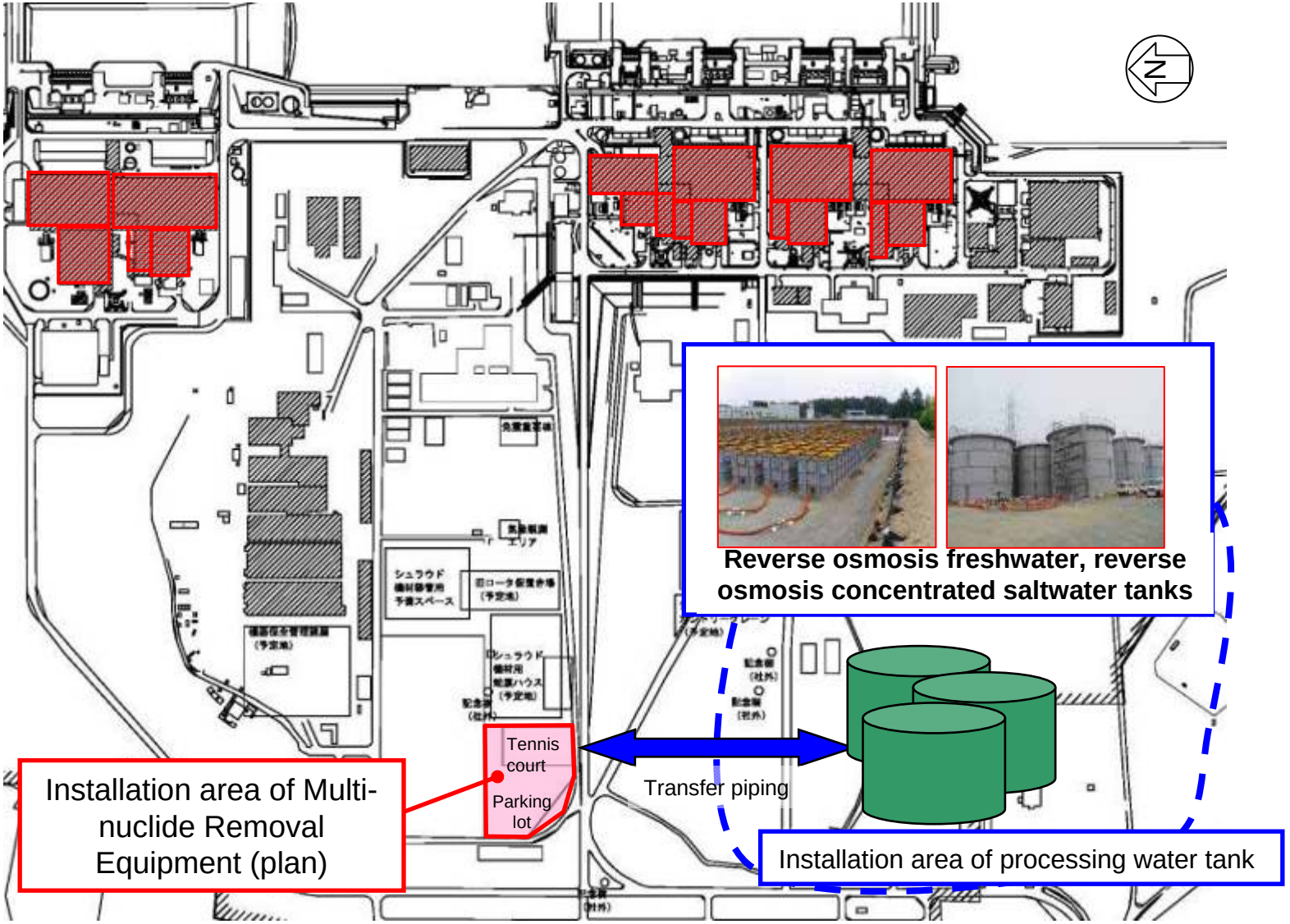


Image of storage container

5. Installation Area (Plan)

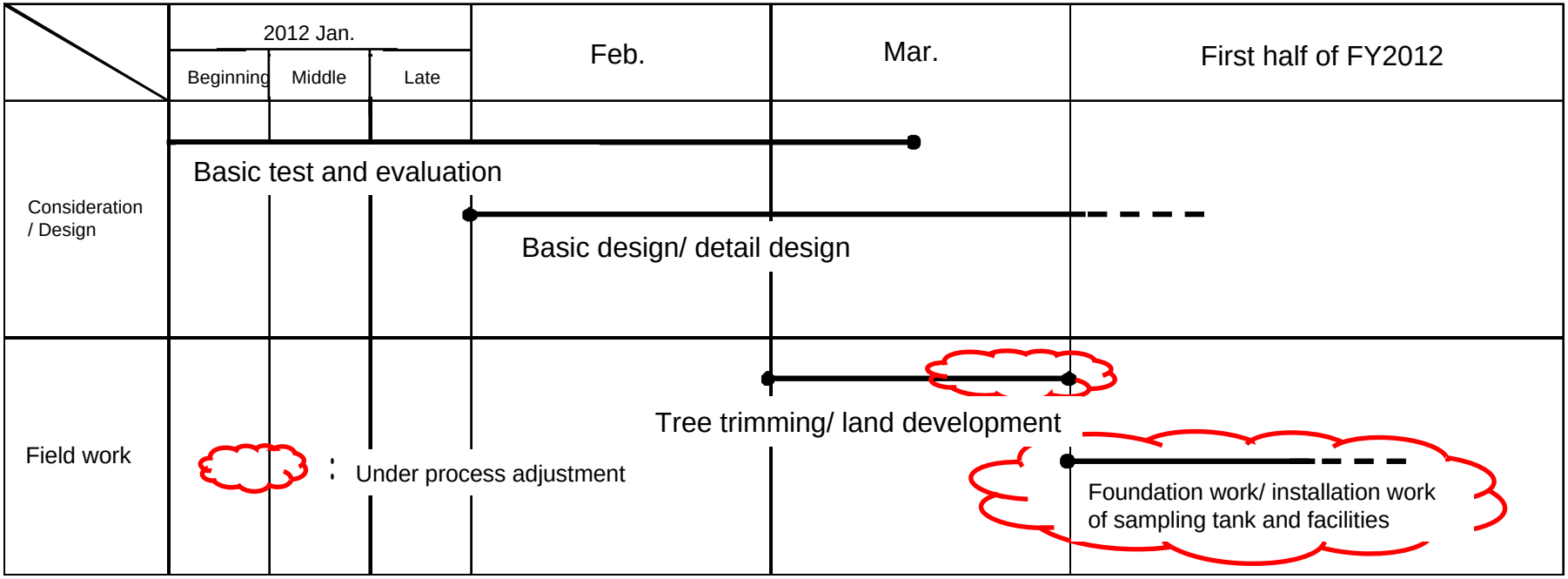
- Installation area plan of Multi-nuclide Removal Equipment



Reference

Ref. 1 Future Plan

Installation schedule



Ref. 2 Selection of Regardable Nuclides

Selection of regardable nuclides

Calculated density of fission products (FP), transuranic elements and corrosion products (CP) in the accumulated water as of one year after the earthquake, and selected nuclides evaluated to exceed 1/100 of the density limit.

✓Fission products (FP), transuranic elements

→Nuclides and their radioactive decays (Cs, Sr etc). Transuranic elements generated during reactor operation (Pu etc.)

✓Corrosion products (CP nuclide)

→Radioactivated substances sourced from corrosion of equipments, devices, piping etc. of reactor plant composition (Fe, Co, Mn etc.)

Ref. 3 Overview of Basic Test Results

Overview of Basic Test results

Classification		Nuclide	Classification		Nuclide	Classification		Nuclide	Classification		Nuclide
FP Nuclide	1	Rb-86	FP Nuclide	17	Sn-126	FP Nuclide	33	Ce-141	Transuranic element	49	Pu-240
	2	Sr-89		18	Sb-124		34	Ce-144		50	Pu-241
	3	Sr-90		19	Sb-125		35	Pr-144		51	Am-241
	4	Y-90		20	Te-123m		36	Pr-144m		52	Am-242m
	5	Y-91		21	Te-125m		37	Pm-146		53	Am-243
	6	Nb-95		22	Te-127		38	Pm-147		54	Cm-242
	7	Tc-99		23	Te-127m		39	Pm-148		55	Cm-243
	8	Ru-103		24	Te-129		40	Pm-148m		56	Cm-244
	9	Ru-106		25	Te-129m		41	Sm-151	CP Nuclide	57	Mn-54
	10	Rh-103m		26	I-129		42	Eu-152		58	Fe-59
	11	Rh-106		27	Cs-134		43	Eu-154		59	Co-58
	12	Ag-110m		28	Cs-135		44	Eu-155		60	Co-60
	13	Cd-113m		29	Cs-136		45	Gd-153		61	Ni-63
	14	Cd-115m		30	Cs-137		46	Tb-160		62	Zn-65
	15	Sn-119m		31	Ba-137m	Transuranic element	47	Pu-238			
	16	Sn-123		32	Ba-140		48	Pu-239			

Evaluated as below density limit, below detection limit (ND) (γ nuclide: 45 nuclides, β nuclide: 3 nuclides)

Below detection limit (ND) based on the gross α radiation measurement results. Evaluating each nuclide's density. (α nuclide: 9 nuclides)

Measurement and evaluation have NOT been completed (β nuclide: 5 nuclides)

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (1/7)

- The targets for this test were ① and ③, (①reverse osmosis concentrated saltwater, ② reverse osmosis freshwater and ③reverse osmosis contaminated water) which had high-radioactive concentration.
- Confirmed that γ nuclide could be removed below detection limit (not detected, ND) against targeted nuclide (45 nuclides).
- Confirmed that β nuclide could be purified to approx. 1/one-million~1/ten-million via gross β radiation measurement. Identifying nuclides with significant density for further purification (scheduled to complete measurement at the beginning of March)
  →After identifying nuclides, reflect on the removal plan.
- Based on the gross α radiation measurement, α nuclide could be cleaned till less than detection limit (ND). Analyzing each nuclide's density.

※ The following evaluation is a provisional report.

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
1	Rb-86 (approx. 19 days)	300	ND < 4800	ND < 1.4	ND < 3500	ND < 1.5	
2	Sr-89 (approx. 51 days)	300	51000000	Not completed	11000000	Not completed	
3	Sr-90 (approx. 29 years)	30	120000000	Not completed	16000000	Not completed	
4	Y-90 (approx. 3 days)	300	120000000	Not completed	16000000	Not completed	

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (2/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
5	Y-91 (approx. 59 days)	300	ND < 130000	ND < 47	ND < 73000	ND < 52	
6	Nb-95 (approx. 35 days)	1000	ND < 540	ND < 0.14	ND < 330	ND < 0.13	
7	Tc-99 (approx. 210000 years)	1000	6.9	ND < 0.40	17	ND < 0.40	
8	Ru-103 (approx. 39 days)	1000	ND < 970	ND < 0.13	510	ND < 0.14	
9	Ru-106 (approx. 1 year)	100	ND < 7600	ND < 1.1	ND < 4700	ND < 1.1	
10	Rh-103m (approx. 2 minutes)	200000	ND < 970	ND < 0.13	510	ND < 0.14	
11	Rh-106 (approx. 30 seconds)	300000	ND < 7600	ND < 1.1	ND < 4700	ND < 1.1	
12	Ag-110m (approx. 25 seconds)	300	ND < 760	ND < 0.13	ND < 430	ND < 0.13	
13	Cd-113m (approx. 14 years)	40	ND < 760	ND < 0.13	ND < 430	ND < 0.13	
14	Cd-115m (approx. 45 days)	300	ND < 760	ND < 0.13	ND < 430	ND < 0.13	

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (3/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
15	Sn-119m (approx. 290 days)	2000	63000	ND < 0.38	140000	ND < 0.37	
16	Sn-123 (approx. 130 days)	400	ND < 68000	ND < 22	ND < 57000	ND < 25	
17	Sn-126 (approx. 100000 years)	200	63000	ND < 0.38	140000	ND < 0.37	
18	Sb-124 (approx. 60 days)	300	ND < 1800	ND < 0.27	ND < 1800	ND < 0.28	
19	Sb-125 (approx. 3 years)	800	63000	ND < 0.38	140000	ND < 0.37	
20	Te-123m (approx. 120 days)	600	ND < 1700	ND < 0.15	ND < 710	ND < 0.12	
21	Te-125m (approx. 57 days)	900	63000	ND < 0.38	140000	ND < 0.37	
22	Te-127 (approx. 9 hours)	5000	ND < 94000	ND < 24	ND < 47000	ND < 18	
23	Te-127m (approx. 110 days)	300	ND < 94000	ND < 24	ND < 47000	ND < 18	
24	Te-129 (approx. 70 minutes)	10000	ND < 14000	ND < 10	ND < 7500	ND < 12	

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (4/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
25	Te-129m (approx. 34 days)	300	ND < 22000	ND < 3.5	ND < 13000	ND < 4.2	
26	I-129 (approx. 15700000 years)	9	ND < 1900	ND < 0.90	ND < 1500	ND < 0.90	
27	Cs-134 (approx. 2 years)	60	4300	ND < 0.26	3400	ND < 0.27	
28	Cs-135 (approx. 2300000 years)	600	ND < 6100	ND < 0.30	ND < 460	ND < 0.32	
29	Cs-136 (approx. 13 days)	300	ND < 580	ND < 0.11	ND < 310	ND < 0.11	
30	Cs-137 (approx. 30 years)	90	6100	ND < 0.30	ND < 460	ND < 0.32	
31	Ba-137m (approx. 3 minutes)	800000	ND < 6100	ND < 0.30	ND < 460	ND < 0.32	
32	Ba-140 (approx. 13 days)	300	ND < 3400	ND < 0.48	ND < 1700	ND < 0.51	
33	Ce-141 (approx. 33 days)	1000	ND < 3100	ND < 0.29	ND < 1300	ND < 0.30	
34	Ce-144 (approx. 285 days)	200	ND < 14000	ND < 0.89	ND < 5000	ND < 0.98	

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (5/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
35	Pr-144 (approx. 17 minutes)	20000	ND < 81000	ND < 180	ND < 47000	ND < 220	
36	Pr-144m (approx. 7 minutes)	40000	ND < 81000	ND < 180	ND < 47000	ND < 220	
37	Pm-146 (approx. 6 years)	900	ND < 1300	ND < 0.18	ND < 680	ND < 0.18	
38	Pm-147 (approx. 3 years)	3000	ND < 980	ND < 0.37	ND < 530	ND < 0.40	
39	Pm-148 (approx. 5 days)	300	ND < 820	ND < 0.11	ND < 430	ND < 0.13	
40	Pm-148m (approx. 41 days)	500	ND < 820	ND < 0.11	ND < 430	ND < 0.13	
41	Sm-151 (approx. 90 years)	8000	ND < 980	ND < 0.37	ND < 530	ND < 0.40	
42	Eu-152 (approx. 14 years)	600	ND < 3800	ND < 0.48	ND < 2000	ND < 0.53	
43	Eu-154 (approx. 9 years)	400	ND < 980	ND < 0.37	ND < 530	ND < 0.40	
44	Eu-155 (approx. 5 years)	3000	ND < 980	ND < 0.37	ND < 530	ND < 0.40	

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (6/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
45	Gd-153 (approx. 240 days)	3000	ND < 2200	ND < 0.37	ND < 1100	ND < 0.40	
46	Tb-160 (approx. 72 days)	500	ND < 2200	ND < 0.37	ND < 1100	ND < 0.40	
47	Pu-238 (approx. 88 years)	4	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
48	Pu-239 (approx. 24110 years)	4	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
49	Pu-240 (approx. 6563 years)	4	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
50	Pu-241 (approx. 14 years)	200	-	Not completed	-	Not completed	
51	Am-241 (approx. 432 years)	5	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
52	Am-242m (approx. 141 years)	5	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
53	Am-243 (approx. 7370 years)	5	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
54	Cm-242 (approx. 163 days)	60	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement

Ref. 4 Overview of Basic Test Results

Basic Test Results of Multi-nuclide Removal Equipment (7/7)

(Bq/L)

No.	Nuclide	Density limit	Reverse osmosis contaminated water		Reverse osmosis concentrated saltwater		Notes
			Before process	After process	Before process	After process	
55	Cm-243 (approx. 29 years)	6	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
56	Cm-244 (approx. 18 years)	7	Under evaluation	Under evaluation	Under evaluation	Under evaluation	Based on gross α radiation measurement
57	Mn-54 (approx. 312 years)	1000	14000	ND < 0.11	45000	ND < 0.12	
58	Fe-59 (approx. 45 days)	400	ND < 780	ND < 0.22	ND < 600	ND < 0.24	
59	Co-58 (approx. 71 days)	1000	ND < 540	ND < 0.11	1200	ND < 0.12	
60	Co-60 (approx. 5 years)	200	3900	ND < 0.16	14000	ND < 0.12	
61	Ni-63 (approx. 100 years)	6000	Not completed	Not completed	Not completed	Not completed	
62	Zn-65 (approx. 240 days)	200	ND < 820	0.26	ND < 630	ND < 0.25	
Gross β			230000000	31	43000000	68	
Gross α			16	ND < 0.066	0.46	ND < 0.066	

※ ND: Below detection limit, <○○: Detection limit

※ ( ): Half-life