Fukushima Daiichi Nuclear Power Station Measurement/verification tank (K4 tank group) circulation/agitation demonstration test results

＜Reference material＞
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- Facilities for ensuring safety when handling ALPS treated water include measurement/verification facilities (K4 tank group). ALPS treated water contains various concentrations of tritium, the 62 nuclides targeted for removal, and carbon-14. The measurement/verification tanks are used to measure the concentrations of the 62 nuclides and carbon-14 to ensure that they fall well below government regulations for discharge into the environment prior to dilution and discharge.
- The K tank group (30 tanks/approximately 30,000m^3) has been divided into three groups (10 tanks each/approximately 10,000m^3) that will be used as holding tanks, measurement/verification tanks, and discharge process tanks, respectively. When taking measurements, the water in the tanks to be analyzed is first circulated/agitated to ensure it is homogeneous.
- In preparation for this process, we used one of the tanks in the K4 tank group to perform agitation demonstration tests in November 2021 and verified that the agitators installed in each tank can sufficiently mix the water inside.
- Based on these results, we linked 10 tanks together to perform circulation demonstration tests in February of this year. All the water in K4 tank group B was circulated by circulation pumps while the agitators in each tank mixed the water. Results from the analysis of tribasic sodium phosphate and tritium showed that water samples taken from the circulation line sampling point after all of the tank water had been circulated twice were representative of all the water in the tanks.
- Based on the aforementioned test results, measurement/verification tanks shall be used in the following manner:
  - Facilities shall be configured in the same manner as they were for the circulation/agitation demonstration tests, and for the initial period after discharge has commenced, circulation/agitation equipment shall be operated for length of time that is needed to circulate twice the amount of water that is in the tanks. (If necessary, a tracer element shall be used to verify optimal operation time).

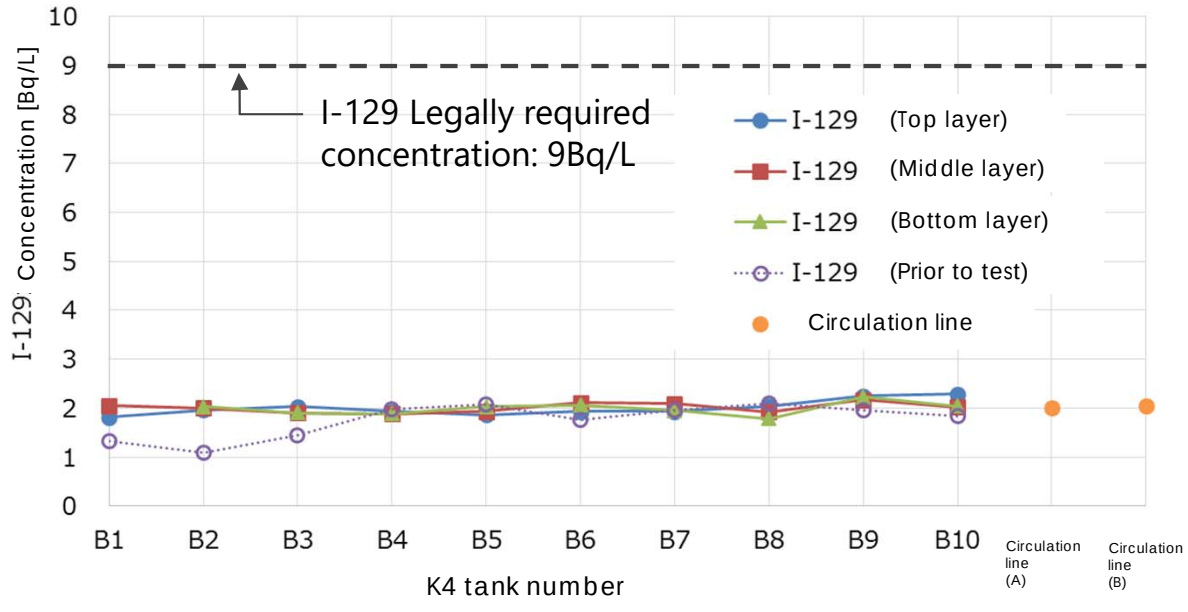
＜ Announced on February 24, 2022 ＞

- The results from the analysis of the primary seven nuclides conducted during the circulation demonstration tests in February of this year have been compiled, and as before, we have verified that the concentrations throughout all the tanks were homogeneous. Details can be found below. Furthermore, during this test, tritium and phosphoric acid, which can be analyzed with great accuracy, were used as primary indicators when analyzing the concentrations of the primary seven nuclides, and the behavior of these two elements was also checked as a precaution.
  - Concentration discrepancies for the primary seven nuclides in each tank either decreased or were approximately the same before and after the test, and the water quality throughout all the tanks was homogeneous.
  - After all the water in the tanks had been circulated twice, water was sampled from the circulation line sampling points (A) (B) and it was found that the concentrations of the primary seven nuclides were approximately equal to the average concentrations for all the tanks.
  - Out of the primary seven nuclides, the concentrations of Cs-134, Ru-106, Sb-125, and Sr-90 were below detectable levels (ND).

※ Primary seven nuclides: Cs-134, Cs-137, Sr-90, I-129, Ru-106, Co-60, Sb-125

Analysis results (1) Post-test tank water sampling results （I-129）

- The following is the sampling results for I-129, which contributes the most to the sum of the ratio of legally required concentrations out of all of the primary seven nuclides.
  - The average concentration of I-129 contained in the samples taken from the top (10m), middle (5m) and bottom (1.5m) layers of water in the 10 tanks after conclusion of the test (after circulating/agitating the water for 144 hours) was 2.00Bq/liter, and the standard deviation was 0.12Bq/liter.
  - The relative standard deviation for I-129 obtained from the sampling results prior to the test was 18.8%. However, since the relative standard deviation after the test had decreased to 5.8%, we have verified that the quality of the water inside the tanks after circulation/agitation was homogeneous.



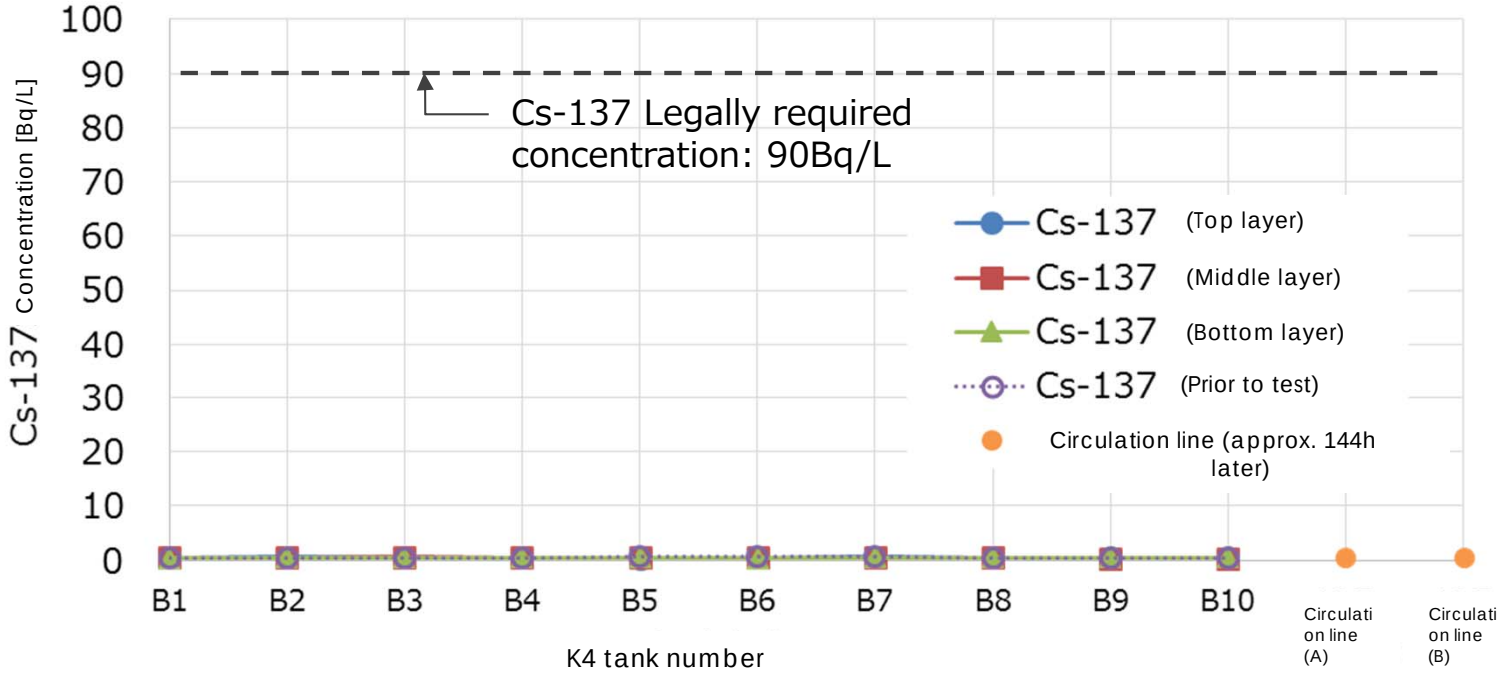
(Unit: Bq/L)

K4 tank number		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Circulation line (A)	Circulation line (B)	**Average**	**Standard deviation※1**	**Relative standard deviation※2**
I-129 concentration prior to the test※3 [Bq/L]		1.32	1.09	1.45	1.98	2.07	1.75	1.97	2.10	1.96	1.83	–	–	**1.75**	**0.33** (3.67%※4)	**18.8 %**
I-129 concentration after the test [Bq/L]	Top layer of tank(10m)	1.82	1.96	2.03	1.94	1.87	1.94	1.94	2.04	2.25	2.29	2.01	2.05	**2.00**	**0.12** (1.33%※4)	**5.8 %**
	Middle layer of tank(5m)	2.05	2.00	1.91	1.89	1.93	2.11	2.09	1.92	2.17	2.02					
	Bottom layer of tank(1.5m)	<2.12	2.03	1.90	1.88	2.03	2.06	1.95	1.78	2.23	2.04					

※1： Measuring value discrepancy decreases as standard deviation decreases. 68.3% value is included in between the average ± standard deviation.
※2： Calculated by dividing standard deviation by the average. Used to compare groups with differing averages.
※3： Samples taken from the K4-B1 tank on May 22, 2020, and samples taken from tanks K4-B2~B10 between June 9 and June 22, 2021
※4： Ration to the legally required concentration

【Reference】Analysis results (2) Post-test tank water sampling results （Cs-137）

- The average concentration of Cs-137 contained in the samples taken from the top (10m), middle (5m) and bottom (1.5m) layers of water in the 10 tanks after conclusion of the test (after circulating/agitating the water for 144 hours) was 0.50Bq/liter, and the standard deviation was 0.05Bq/liter. Furthermore, a comparison of sampling results from before the tests showed that there is no deviation between the tanks before and after the test, and that water throughout all the tanks was homogeneous also after the circulation/agitation demonstration test.



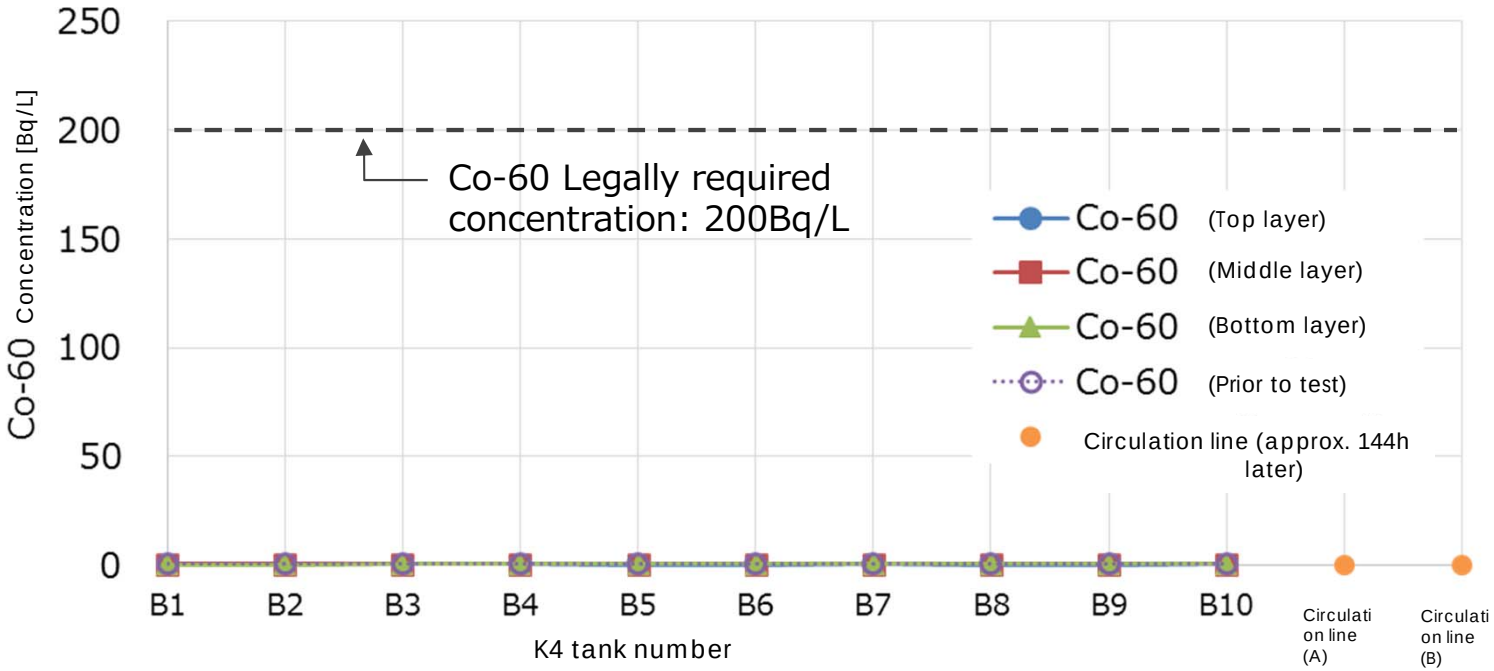
(Unit: Bq/L)

K4 tank number		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Circulation line (A)	Circulation line (B)	Average	Standard deviation	Relative standard deviation
Cs-137 concentration before the test※1 [Bq/L]		0.47	0.45	0.57	0.44	0.63	0.69	0.59	0.49	0.54	0.43	–	–	**0.53**	**0.08** (0.09%※2)	**15.8 %**
Cs-137 concentration after the test [Bq/L]	Top layer of tank(10m)	0.48	0.57	0.57	0.53	0.43	0.53	0.64	0.52	0.51	0.52	0.66	0.47	**0.50**	**0.05** (0.06%※2)	**10.4 %**
	Middle layer of tank(5m)	0.50	0.50	0.63	0.51	0.55	0.56	0.45	0.46	0.42	0.44					
	Bottom layer of tank(1.5m)	0.42	0.46	0.51	0.50	0.51	0.42	0.50	0.53	0.46	0.50					

※1： Samples taken from the K4-B1 tank on May 22, 2020, and samples taken from tanks K4-B2~B10 between June 9 and June 22, 2021
※2： Ratio to the legally required concentration

【Reference】Analysis results (3) Post-test tank water sampling results （Co-60）

- The average concentration of Co-60 contained in the samples taken from the top (10m), middle (5m) and bottom (1.5m) layers of water in the 10 tanks after conclusion of the test (after circulating/agitating the water for 144 hours) was 0.40Bq/liter, and the standard deviation σ was 0.08Bq/liter. Furthermore, a comparison of sampling results from before the tests showed that there is no deviation between the tanks before and after the test, and that water throughout all the tanks was homogeneous also after the circulation/agitation demonstration test. Furthermore, even though an increase in the standard deviation was seen before and after the test, the fluctuation was small compared to legally required concentrations, and we therefore do not believe the fluctuation to be significant.



(Unit: Bq/L)

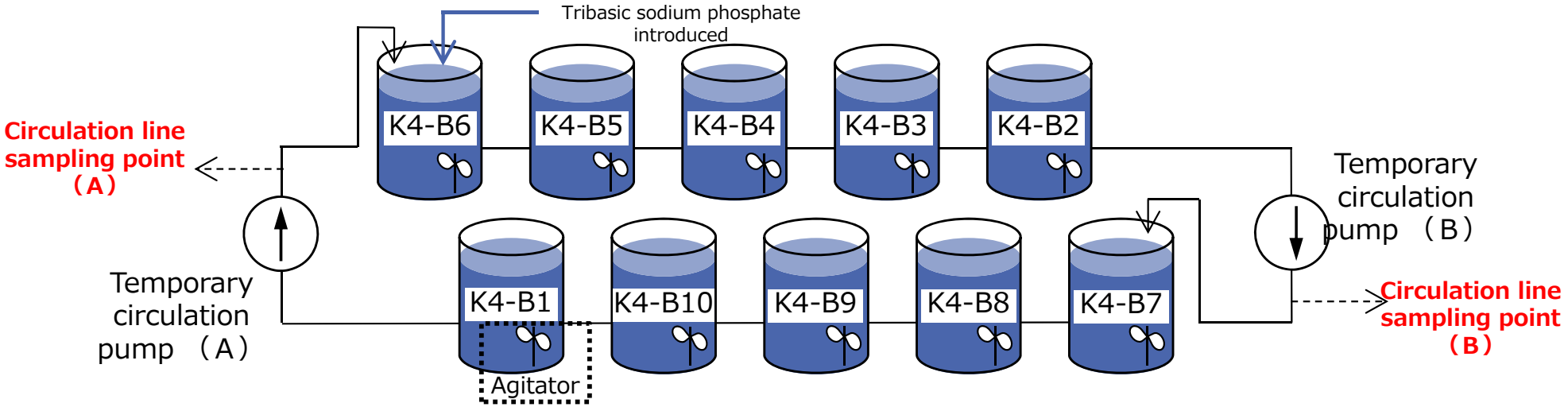
K4 tank number		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	Circulation line (A)	Circulation line (B)	Average	Standard deviation	Relative standard deviation
Co-60 concentration before the test※1 [Bq/L]		0.56	0.49	0.52	0.46	0.51	0.44	0.42	0.66	0.46	0.53	–	–	**0.51**	**0.06** (0.03%※2)	**12.8 %**
Co-60 concentration after the test [Bq/L]	Top layer of tank(10m)	0.32	0.53	0.43	0.36	0.27	0.29	0.31	0.25	0.31	0.52	0.42	0.43	**0.40**	**0.08** (0.04%※2)	**20.4 %**
	Middle layer of tank(5m)	0.34	0.47	0.53	0.41	0.40	0.47	0.33	0.47	0.47	0.37					
	Bottom layer of tank(1.5m)	0.30	0.29	0.34	0.50	0.43	0.52	0.41	0.50	0.43	0.45					

※1： Samples taken from the K4-B1 tank on May 22, 2020, and samples taken from tanks K4-B2~B10 between June 9 and June 22, 2021
※2： Ratio to the legally required concentration

【Reference】 Circulation/agitation demonstration test details

Date of implementation	February 7~February 13, 2022		
Test time	Approximately 144 hours		
Tanks used	K4-group B (10 tanks)		
Reagent※1	Tribasic sodium phosphate※2 (Introduced via manhole on the top of tank K4-B6)		
Sampling	Before the test	During the test※3	After the test
Sampling point	Inside tanks K4-B1～B10 (5m)	Circulation line, two locations	Tanks K4-B1～B10 Top(10m)/Middle(5m)/Bottom(1.5m)
Sample volume	1L each, 10 samples in total	1L each※5, 28 samples in total	6L each, 30 samples in total
Analysis target	Phosphoric acid※4	Phosphoric acid※5	Phosphoric acid + primary seven nuclides※6+Tritium

※1： A reagent that does not exist inside the tank was introduced in order to verify concentration distribution.
※2： The amount of tribasic sodium phosphate introduced is 1/100 the regulatory limit for wastewater as stipulated by Fukushima Prefecture ordinances (phosphorus content [daily average: 8ppm]) and will have no impact on the environment.
※3： Samples taken every six hours during the first 24 hours of the test, and then every 12 hours from the 24th hour through the 144th hour of the test.
※4： The primary seven new clients (Cs-134, Cs-137, Sr-90, I-129, Ru-106, Co-60, Sb-125) +tritium were not analyzed since there are initial values (refer to slide 6) for these elements.
※5： 6L samples were taken at the 6, 72 and 144 hour marks, at which times the primary seven nuclides and tritium were added to phosphoric acid as analysis targets.
※6： Primary seven nuclides (Cs-134, Cs-137, Sr-90, I-129, Ru-106, Co-60, Sb-125)



【Reference】Analysis results summary (as reported prior)

- Based on the results of the circulation/agitation demonstration test we have determined that it is possible to obtain a representative sample by circulating/agitating the water in the tanks.
  - During this test, the total amount of tribasic sodium phosphate was introduced to one tank（K4-B6）prior to the test. And, although the test was commenced under these extremely conservative initial conditions, the average concentration of phosphoric acid contained in the water sampled from circulation line sampling points (a) and (B) after all the water in the tanks had been circulated twice was 84.5ppb, which is almost equal to the theoretical value of 80ppb.
  - The average concentration of phosphoric acid contained in the water sampled from the tanks under these conservative initial conditions was 86ppb, and the standard deviation was 9ppb, thereby showing a slight discrepancy. However, despite this discrepancy, the average tritium concentration in the tank was1.51×10^5 Bq/L, and the standard deviation was0.029×10^5Bq/L, thereby verifying that circulating/agitating the water in the tank made the quality of water homogeneous.

- In light of the results of this test, the facilities shall be configured in the same manner as was used for the test, and for the initial period after discharge has commenced, the water will be circulated/agitated for length of time necessary to ensure that all the water in the tank has been circulated twice.
- If necessary, a tracer element shall be used to verify optimal circulation/agitation time to verify optimal operation time.