Evaluation of the report of Tokyo Electric Power Company regarding the leakage from the RO-3 contaminated water treatment facility desalination system (reverse osmosis membrane system) at Fukushima Daiichi Nuclear Power Station

15 April 2015
Nuclear Regulation Authority, Japan

1. Overview

Around 9:35 on 9 October 2013, while performing work to replace a pressure hose with polyethylene piping (hereinafter referred to as "PE piping") in the building (hereinafter referred to as "cornice house") which houses the contaminated water treatment facility desalination system (hereinafter referred to as "RO-3[1]"), a connecting part of an adjoining pressure hose that was not subject to removal (hereinafter referred to as the "cam lock") was mistakenly removed, resulting in water leakage passing through the pipe (refer to Figures 1 through 3). Six of the eleven workers were found to have bodily contamination and thus underwent decontamination before exiting the site.

Tokyo Electric Power Company (hereinafter, referred to as "TEPCO") concluded that, although the leakage did not spread outside the dike[2] located inside the cornice house, the degree of leakage exceeded the standard for negligible leakage and therefore the event was subject to Article 18, item 12 of the Regulations Concerning Operational Safety of Nuclear Reactor Facilities and Physical Protection of Specified Nuclear Fuel Materials in Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company.[3]

In the same day, the Nuclear Regulation Authority (hereinafter, referred to as "NRA") received the report regarding accidents and failures based on the Article 62-3 of the Act on Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors from Tokyo Electric Power Company (hereinafter, referred to as "TEPCO").

Subsequently, the NRA received the report regarding causes and countermeasures of the aforementioned event (the final report) from TEPCO as of 6 December 2013 (partially corrected on 31 October 2014) and the NRA reviewed the contents and summarized the evaluation result.

Report from TEPCO
http://www.nsr.go.jp/activity/bousai/trouble/20141031-3.html

[1] A reverse osmosis membrane-type contaminated water treatment system

[2] A concrete foundation and dike designed to prevent the water in the tank from leaking out into the site even if water leaks outside the tank

[3] An analysis of the radioactivity concentration of the leaked water conducted at a later date showed that the total beta radioactivity concentration was 3.4×10^7 Bq/L, and the amount of leakage was approximately 11 m^3. Based on these results, it was confirmed that the radioactivity concentration exceeded the standard for cases in which the amount of radioactivity is very small (1.0×10^{10} Bq) provided for in "Concerning operation under Article 18 of the Regulations Concerning Operational Safety of Nuclear Reactor Facilities and Physical Protection of Specified Nuclear Fuel Materials in Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (internal regulations)" (established by the NRA).

2. Overview of the report submitted by TEPCO

(1) Investigation of the situation at the time the leakage occurred

(1)-1 Situation at the time the leakage occurred

The worker who was replacing the pressure hose with PE piping as part of reliability improvement measures misidentified an adjoining pressure hose as being the one subject to replacement and mistakenly removed a cam lock with no identification marking (refer to Figures 4 and 5).

The adjoining pressure hose from which the cam lock was mistakenly removed was in operation and had water passing through it; therefore, leakage occurred. The leakage was stopped by shutting down the waste liquid supply pump and reconnecting the cam lock.

Although the amount of leaked water was approximately 11 m^3, it remained inside the cornice house dike and did not spread outside the dike. In terms of total beta, the radioactive concentration was 3.4×10^7 Bq/L, while the total amount of radioactivity was approximately 3.7×10^{11} Bq.

The leakage was caused by performing the work without sufficient safety measures such as isolation as well as failing to provide clear identification markings.

(1)-2 Communication situation after the leakage occurred

Although workers are supposed to immediately contact the Chief of the Restoration Section from the site when leakage or a similar problem occurs, the worker prioritized restoring the removed cam lock and did not contact the Chief of the Restoration Section. In addition, upon noticing the leakage alarm, the contracted operator of the water treatment facility control room did not contact the Chief of the Restoration Section directly but instead contacted the person in charge of operation management.

There was a delay in communication because the rule to immediately contact the Chief of the Restoration Section was not strictly obeyed.

(2) Bodily contamination situation and evaluation of radiation exposure

When contamination occurred from the cam lock, the workers did not immediately leave the site but instead performed water cut-off work without sufficient equipment. For this reason, six of the eleven workers were found to have bodily contamination below the neck (refer to Figure 6 and Table 1). For five of these six workers who were wearing anoraks, contamination may also have occurred when taking off the anoraks because they did not first remove the contaminated water and other substances on the anorak surface.

The results of an evaluation of radiation exposure conducted on the six contaminated workers confirmed that the annual effective dose limit (50 mSv) and cumulative effective dose limit for five years (100 mSv) as well as the equivalent dose limit (eye lens: 150 mSv, skin: 500 mSv) had not been exceeded (refer to Table 2).

Bodily contamination occurred because the workers did not implement sufficient radiation protection measures; for example, they performed water cut-off work without sufficient equipment and did not remove contaminated water and other substances on their anoraks when removing the anoraks.

(3) Countermeasures

(3)-1 Countermeasures against leakage from the cam lock

a. As a procurement requirement, the additional work specifications stipulate that identification markings must be provided and checked by the work supervisor when removing or attaching important cables, piping or the like during remodeling or similar work.

b. The safety assessment guidelines have been reviewed so that risks present during work can be reduced by accurately extracting them during safety assessments.

(3)-2 Countermeasures related to the delay in contacting the Chief of the Restoration Section[4]

Reminders were given at meetings with cooperating companies and through the company intranet that it is necessary to immediately contact the Chief of the Restoration Section should an accident or fire occur.

(3)-3 Countermeasures against bodily contamination

The following rules were disseminated at meetings with cooperating companies and through the company intranet.

a. Leave the leakage site if there is a risk of bodily contamination, even if it has become necessary to perform unscheduled work.

b. When performing restoration work, including water cut-off work, follow the stipulated rules and wear appropriate protective equipment.

c. Before taking off anoraks[5] on which contaminated water is present, carry out appropriate measures, such as removing the contaminated water.

3. NRA's evaluation with regard to the report submitted by TEPCO and future response

(1) Environmental impact (spread of contaminated water)

The NRA concludes that there was no environmental impact based on the fact that the leaked water (approximately 11 m^3, radioactivity of approx. 3.7×10^{11} Bq for total beta) remained inside the cornice house dike.

(2) Exposure radiation dose

When the leakage occurred, eleven workers performed water cut-off work without sufficient equipment, and bodily contamination was found on six workers. They exited the site after undergoing decontamination until the exit criterion (13,000 cpm) was satisfied. The results of evaluation of the effective dose due to gamma rays and the equivalent dose to the skin due to beta rays for these eleven workers indicated their doses were significantly below the annual dose limits (refer to Tables 1 and 2).

In addition, the effective dose due to gamma rays and the equivalent dose to the skin due to beta rays for the workers who patrolled the RO-3 area before and after the leakage were evaluated; the results showed no obvious changes before and after discovery of the leakage (refer to Table 3). The NRA thus concludes that there has been no exposure leading to concern.

(3) Countermeasures

TEPCO had completed implementation of the following countermeasures (refer to Table 4) by March 2014. The NRA has evaluated them as follows, and countermeasures

summarized by TEPCO shall be checked about its implementation situation at an appropriate timing by safety inspection, etc.

(i) Countermeasures against leakage from the cam lock

Based on the fact that the misidentification of the cam lock was due to the failure to require identification markings at the time of procurement, a requirement that identification markings be added and checked by the work supervisor has been stipulated in the additional specifications for work.

Based on the fact that the leakage occurred because the adjoining pressure hose from which the cam lock was mistakenly removed was in operation and water was passing through it, a review of the safety assessment guidelines has been conducted so that safety measures (such as conducting risk assessment and removing risks before starting work) are taken.

The NRA concludes that these countermeasures will be effective in reducing the leakage risk if implemented appropriately.

(ii) Countermeasures against bodily contamination

Based on the assumption that bodily contamination of the workers occurred because they performed water cut-off work without sufficient equipment and did not first remove contaminated water present on their anoraks when removing the anoraks, measures to help workers sufficiently understand the rules have been implemented, including dissemination of requirements regarding radiation protection at meetings as well as through the company intranet. The NRA considers these countermeasures to be reasonable.

(iii) Countermeasures against the delay in contacting the Chief of the Restoration Section

The necessity of immediately contacting the Chief of the Restoration Section in the case of an accident or fire has been thoroughly publicized. The NRA considers this countermeasure to be reasonable and has judged it necessary to steadily carry out such publicizing.

[4] Personnel who gather information related to restoration work and provide collective instructions on how to handle problems.

[5] Wear to protect against contamination made from polyvinyl chloride.

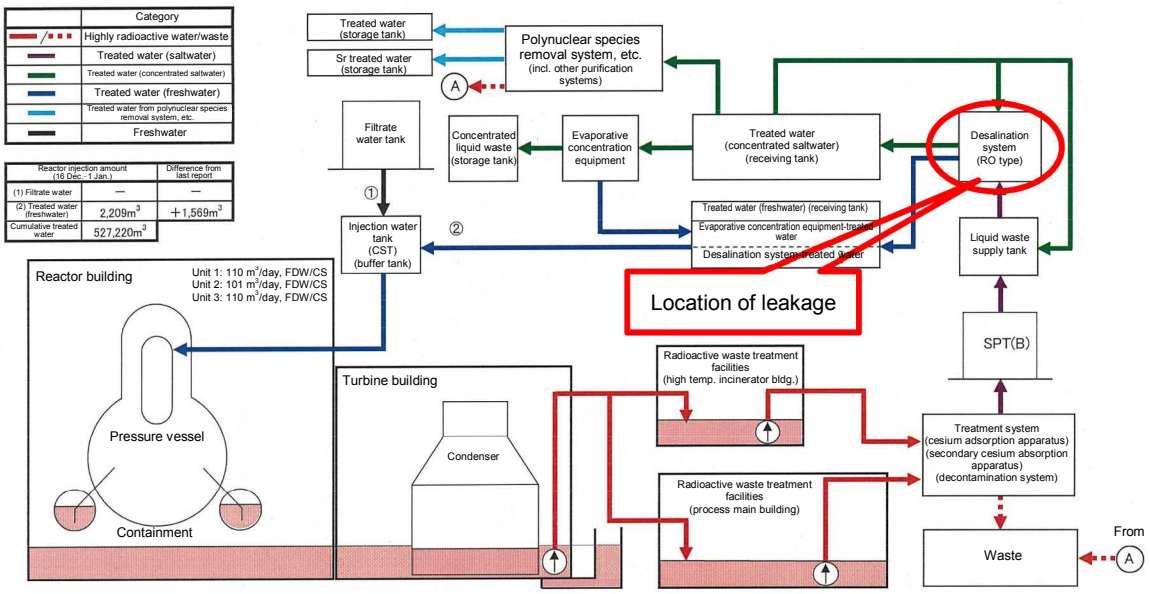


Figure 1 Overview of the processing route for accumulated highly radioactive water (based on the Secretariat of the NRA's document for a meeting with TEPCO)

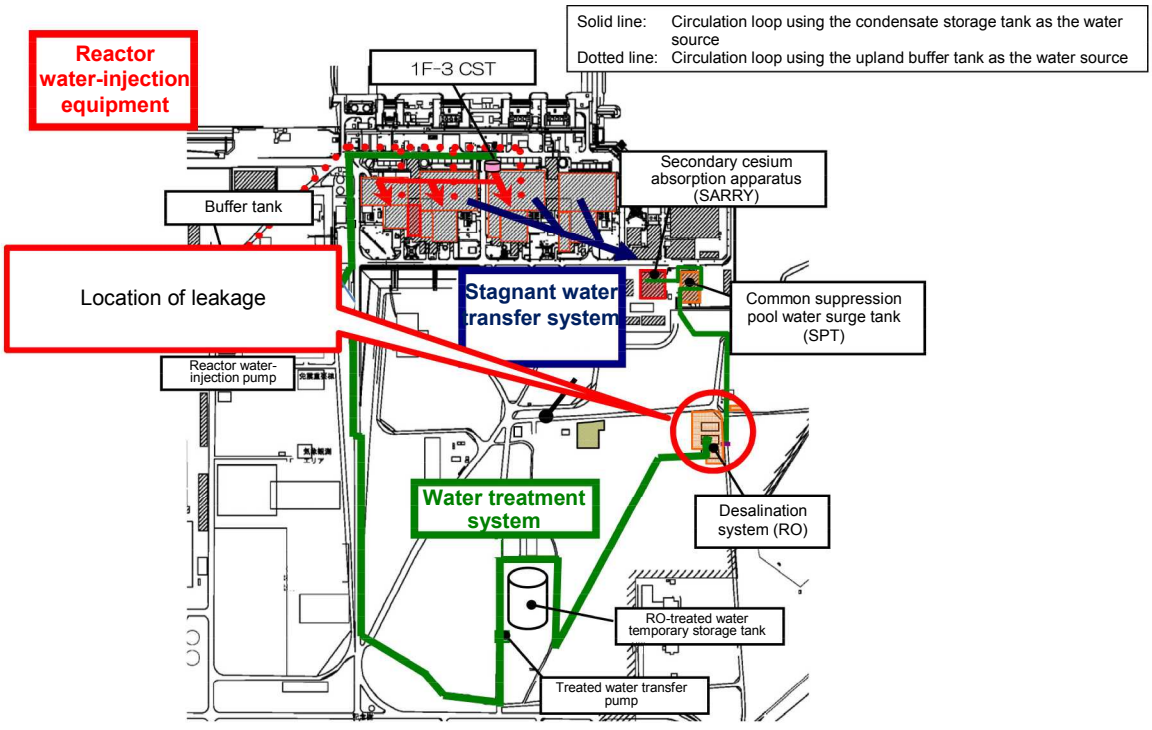
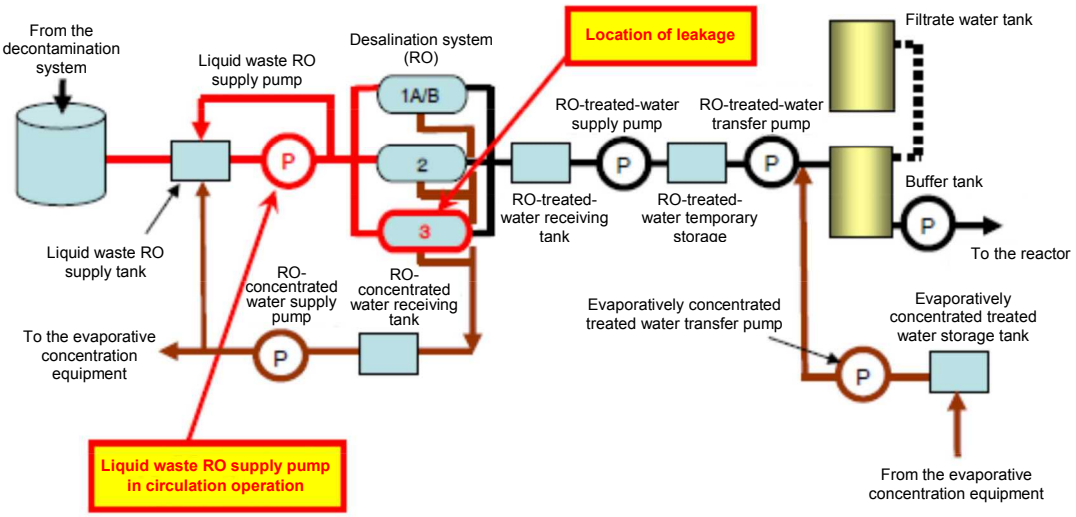


Figure 2 Approximate position of the leakage location (extracted from the Secretariat of the NRA's document for a meeting with TEPCO)

Schematic diagram of the desalination system



Structure of the RO-3 cornice house

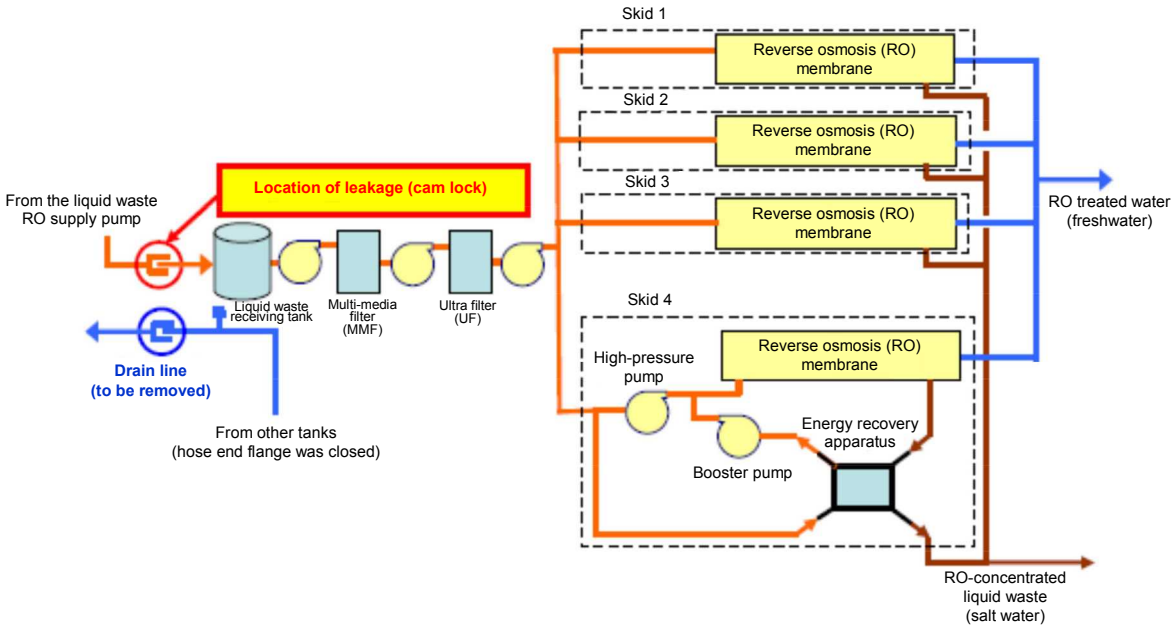
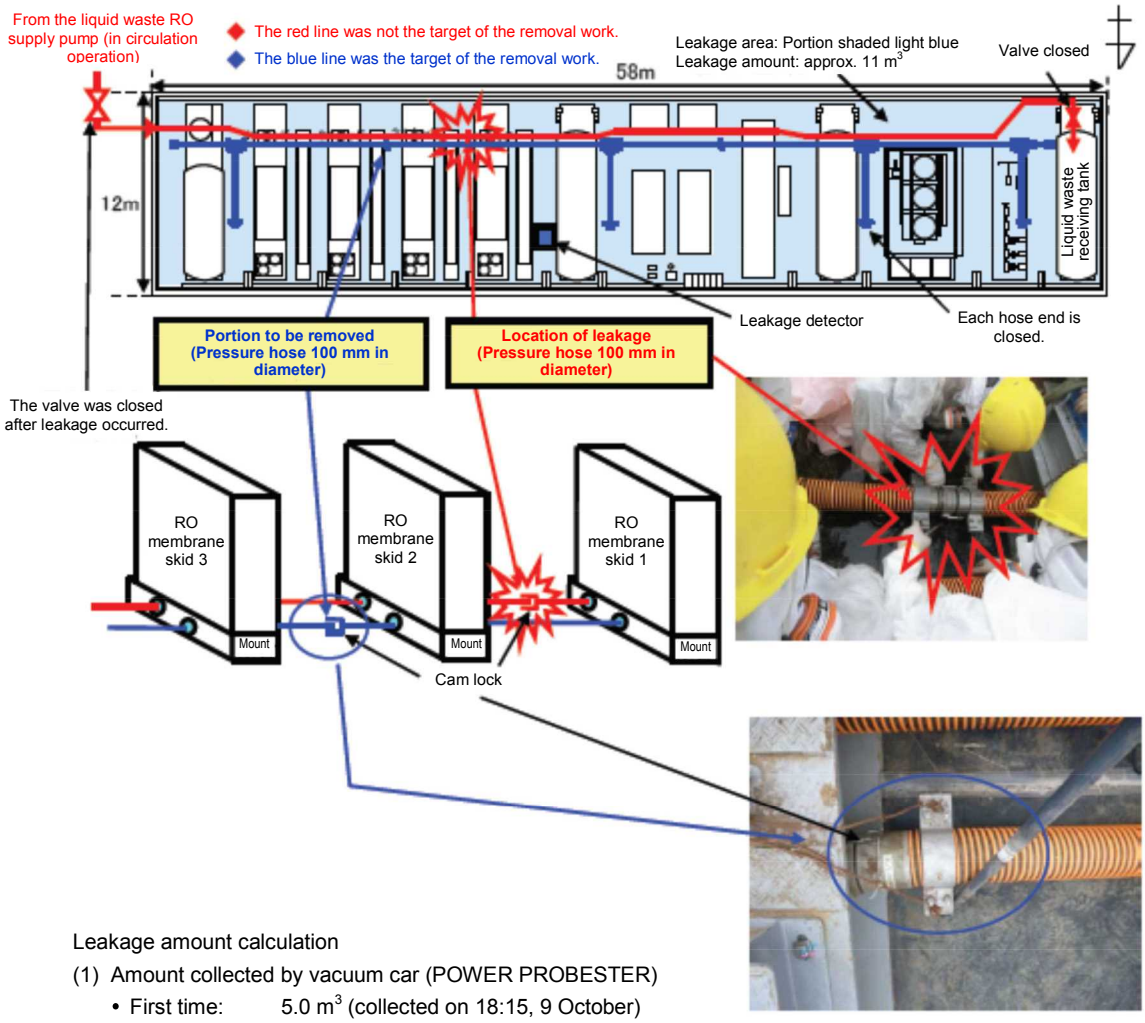


Figure 3 Overview of the desalination system (extracted from the TEPCO report)

Leakage situation in the RO-3 cornice house and leakage amount



Leakage amount calculation

(1) Amount collected by vacuum car (POWER PROBESTER)

- First time: 5.0 m^3 (collected on 18:15, 9 October)
- Second time: 3.0 m^3 (collected on 20:30, 9 October)
- Third time: 2.3 m^3 (collected on 19:43, 10 October)
- Total: 10.3 m^3

(2) Amount of remaining water collected

- Amount collected by buckets, etc., and placed in the temporary tank: 0.4 m^3
- Amount collected by absorption mats, waste paper, etc.: 0.4 m^3
- Total: 0.8 m^3

(3) Total collection amount

(1) 10.3 m^3 + (2) 0.8 m^3 = 11.1 m^3

Leakage amount = approx. 11 m^3

Figure 4 Leakage situation in the RO-3 cornice house and leakage amount (extracted from the TEPCO report)

Situation regarding cam lock removal while removing the pressure hose to replace it with PE piping

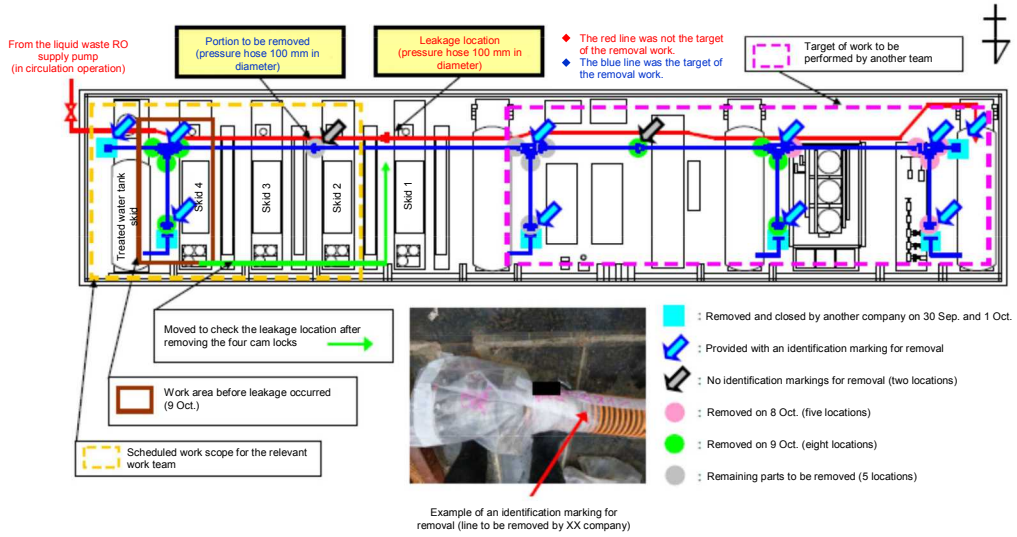


Figure 5 Situation regarding cam lock removal while removing the pressure hose to replace it with PE piping (extracted from the TEPCO report)

Work and assignment situation at the site before and after leakage occurred

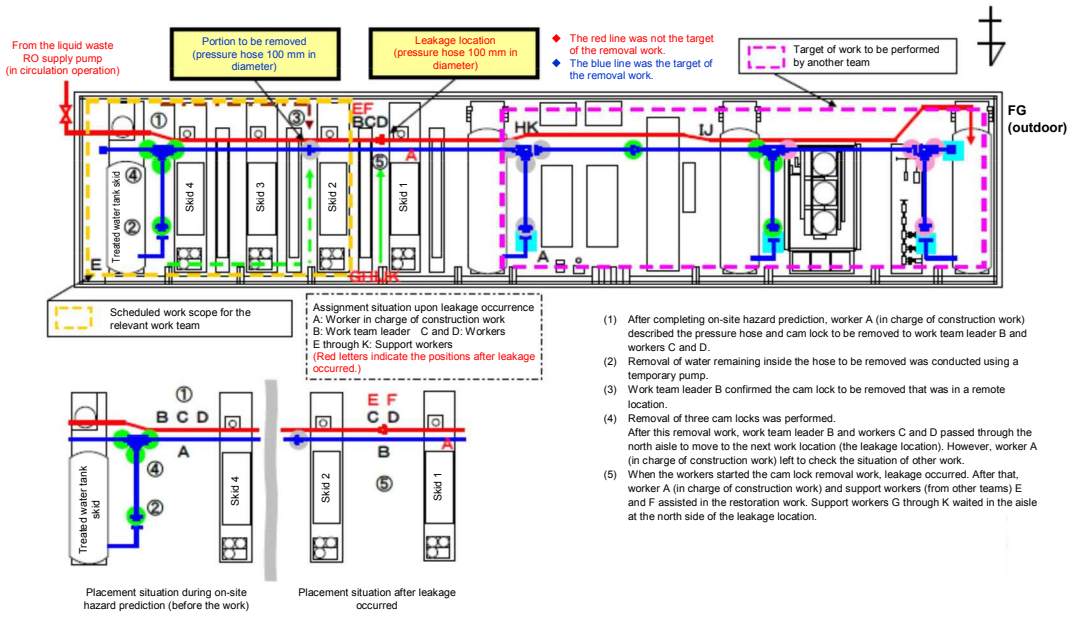


Figure 6 Work and assignment situation at the site before and after leakage occurred (extracted from the TEPCO report)

Table 1 Actual radiation doses of workers and contamination situation (extracted from the TEPCO report)

Cooperating company workers	Equipment used during work (all workers were wearing full-face masks, two layers of rubber gloves, and cotton work gloves)		Actual dose (APD value)		Bodily contamination (before decontamination)			Bodily contamination (after decontamination)	
			Gamma dose	Beta dose	Yes/No	Contaminated region	Measured value	Contaminated region	Measured value
Worker A in charge of construction work	Coveralls	Shoes	0.30 mSv	0.2 mSv	Yes	Left heel	90kcpm	Left heel	<4Bq/cm^{2}[※1]
Work team leader B	Anorak	Shoes	0.15 mSv	1.2 mSv	Yes	Lower abdomen —	25kcpm —	— Upper left arm	— 2.8kcpm
Worker C	Anorak	Boots	0.15 mSv	0.7 mSv	Yes	Buttocks —	10kcpm —	Buttocks Left calf	0.9kcpm 2.0kcpm
Worker D	Anorak	Shoes	0.12 mSv	0.6 mSv	Yes	Right foot bottom	4kcpm	Right foot bottom	0.9kcpm
Worker E (support worker[2])	Anorak	Boots	0.42 mSv	0.7 mSv	Yes	Left thigh Abdomen	18kcpm 4kcpm	Left thigh Abdomen	1.0kcpm 1.0kcpm
Worker F (support worker[2])	Anorak	Shoes	0.12 mSv	0.2 mSv	Yes	Right foot bottom Left foot bottom	40kcpm 60kcpm	Right foot bottom Left foot bottom	11.0kcpm 12.4kcpm
Worker G (support worker[2])	Anorak	Shoes	0.19 mSv	0.0 mSv	No	—	—	—	—
Worker H (support worker[2])	Anorak	Shoes	0.47 mSv	0.0 mSv	No	—	—	—	—
Worker I (support worker[2])	Anorak	Shoes	0.48 mSv	0.0 mSv	No	—	—	—	—
Worker J (support worker[2])	Anorak	Shoes	0.31 mSv	0.0 mSv	No	—	—	—	—
Worker K (support worker[2])	Anorak	Shoes	0.47 mSv	0.0 mSv	No	—	—	—	—

[1] Exited by passing through the body surface monitor
[2] Workers who had been engaged in other work

Table 2 Results of equivalent dose evaluation of workers with bodily contamination (extracted from the TEPCO report)

Cooperating company workers	Most contami-nated region	Actual dose on the day of work (APD)		Skin equivalent dose due to contamina-tion (mSv)	Dose resulting from work on the day (mSv)			Dose situation for FY2013 (mSv)			Cumulative effective dose for 5 years (mSv)
		Gamma dose (mSv)	Beta dose (mSv)		Effective dose	Equivalent dose (skin)	Equivalent dose (eye lens)	Effective dose	Equivalent dose (skin)	Equivalent dose (eye lens)	
Worker A (in charge of construction work)	Left heel	0.30	0.2	4.8	0.35	5.3	0.5	9.13	20.0	11.1	14.02
Work team leader B	Lower abdomen	0.15	1.2	1.1	0.18	2.5	1.4	10.81	25.1	22.8	49.35
Worker C	Buttocks	0.15	0.7	0.5	0.16	1.4	0.9	2.55	3.8	3.3	3.51
Worker D	Right foot bottom	0.12	0.6	0.1	0.13	0.8	0.7	10.28	20.6	18.5	46.27
Worker E (support worker[2])	Left thigh	0.42	0.7	0.8	0.44	1.9	1.1	4.83	8.5	5.5	8.45
Worker F (support worker[2])	Left foot bottom	0.12	0.2	46.7[※2]	0.18	5.5	0.3	2.93	50.0	2.6	31.28
						Notified dose limit (mSv)		50	500	150	100

[1] Workers who had been engaged in other work
[2] Due to the fact that a dose of 12,400 cpm was observed on a toenail of the worker at the time of exiting on the day the event occurred, cooperating company A performed dose evaluation until the dose fell (to 7,500 cpm) sufficiently below the exit criteria (13,000 cpm), and this value was made the skin equivalent dose resulting from contamination. The skin equivalent dose was evaluated based on the Ordinance on Prevention of Ionizing Radiation Hazards.

Table 3 Evaluation of radiation exposure received during patrols (extracted from the Secretariat of the NRA's document for a meeting with TEPCO)

Differences in workers' exposure doses	Effective dose (gamma rays)		Equivalent dose (skin, beta rays)	
	Annual dose limit 50 mSv		Annual dose limit: 500 mSv	
	Avg. dose per a single entry [mSv]	Max. dose per a single entry [mSv]	Avg. dose per a single entry [mSv]	Max. dose per a single entry [mSv]
Tank patrol				
Before finding leakage (2-8 Oct.)	0.04	0.17	0.01	0.1
On the day the leakage was found (9 Oct.)	0.06	0.17	0.01	0.1
After finding leakage (10-16 Oct.)	0.04	0.16	0.02	0.1

Table 4 Countermeasures completion time (extracted from the Secretariat of the NRA's document for a meeting with TEPCO)

Category	Countermeasure	Date completed
Countermeasures related to leakage from the cam lock	Clarification of requirements regarding adding identification markings upon procurement	12 December 2013
	Identification of each skid number	Early December 2013
Countermeasures related to bodily contamination	Review of the safety assessment guidelines (system to appropriately extract and reduce the risks from the perspectives of the 3 H's [*Hajimete*: work to be performed for the first time, *Hisashiburi*: work that has not been performed for a long time, *Henkou*: work in which changes have been made])	27 March 2014
	Establishment of a system to review safety measures	Mid November 2013
	Cooperating companies were requested to implement countermeasures against bodily contamination.	12 December 2013
	The above measures were publicized to company employees.	25 December 2013
Countermeasures related to the delay in contacting the Chief of the Restoration Section	Employees were reminded to contact the Chief of the Restoration Section should an accident or fire occur.	25 December 2013
	Cooperating companies were requested to contact the Chief of the Restoration Section should an accident or fire occur.	12 December 2013
	Creation and dissemination of service area maps for PHS and mobile phones	12 December 2013