Causes and Countermeasures for the Leak of Water Containing Radioactive Substances from the High Temperature Incinerator Building

February 15, 2024

Tokyo Electric Power Company Holdings, Inc.

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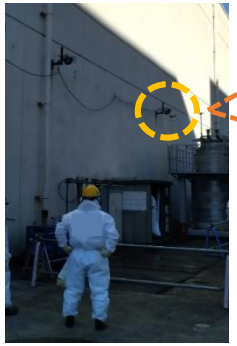
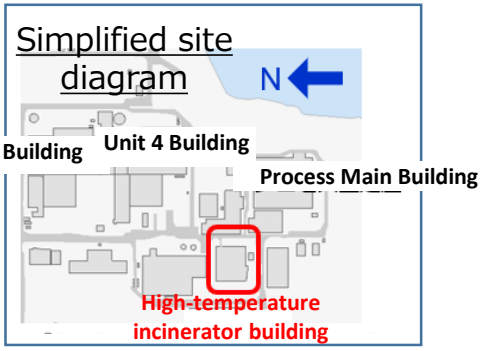
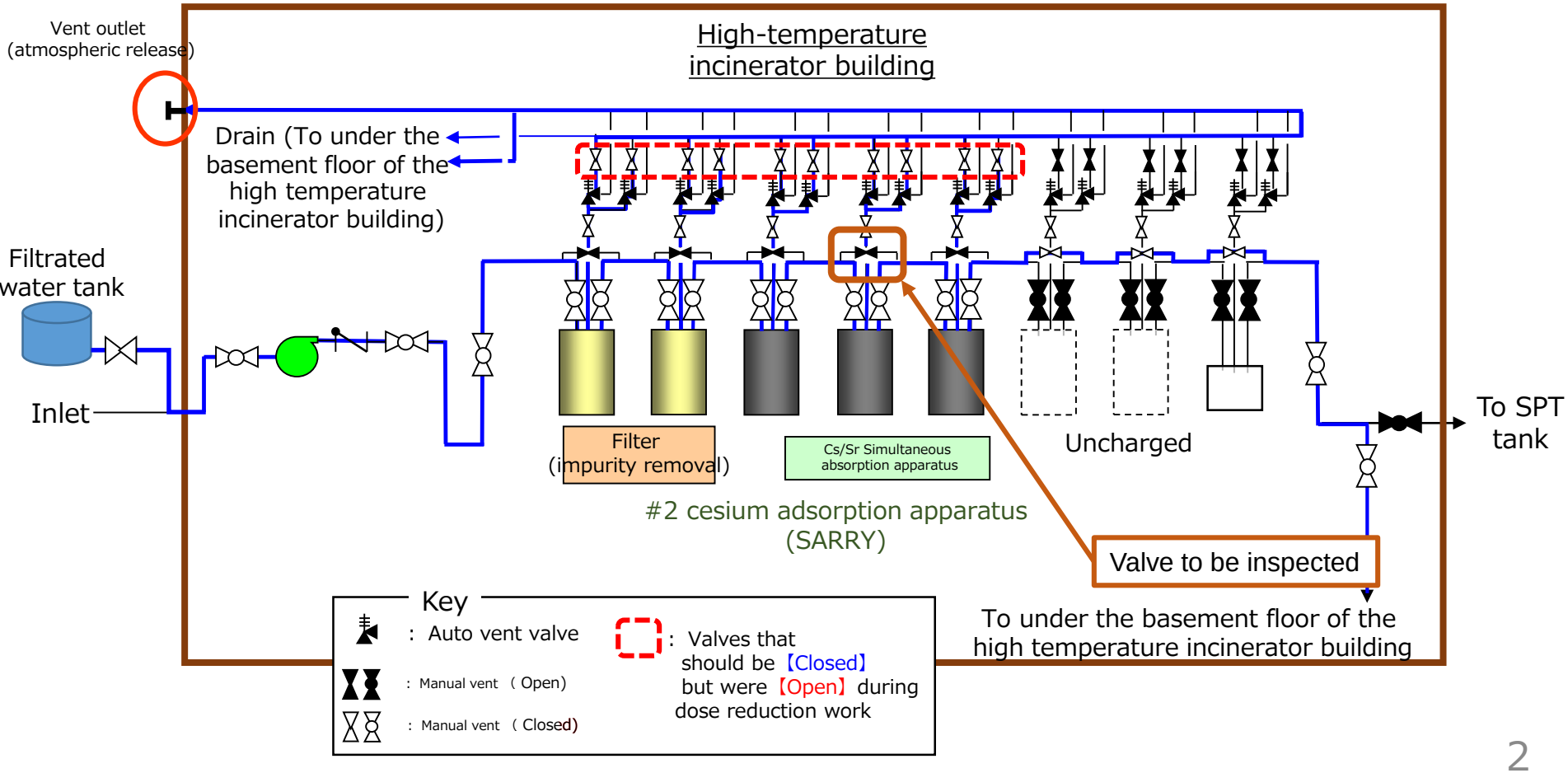
1. Incident overview

- On February 7 at around 8:53 AM, a contractor worker discovered water leaking from a vent outlet (for venting hydrogen generated inside the adsorption apparatus) for the #2 cesium adsorption apparatus (SARRY) located approximately 5m off the ground on the outside of the east wall of the high-temperature incinerator building.
- At around the same time, filtrated water was being passed through SARRY, which was shut down, in order to inspect valves as part of dose reduction work. At around 9:10 AM, the master valve for the filtrated water was closed and it was confirmed at around 9:16 AM that the leak had stopped.
- The leaked water consisted of system water and filtrated water, and the resulting approximate 1mm deep puddle covered an area approximately 4m x 4m on the metal plates laid on the ground in this location. Since it was possible that the leaked water seeped into the ground through the gaps in the metal plates, as an emergency measure the aforementioned area has been cordoned off.
- Workers were not subject to body contamination, and we have confirmed that there has been no impact on the external environment in conjunction with the leak by checking site border monitoring posts, continuous dust monitors, and drainage channel monitors. (No impact on the external environment has been seen as of February 15)
- On February 7, a simplified assessment of the amount of radioactive substances that leaked (calculated using approximate 5.5 m^3 as the amount of the leak) produced α gross γ (Cs-137 assessment) assessment of approximately 22 billion Bq, so TEPCO determined that the leak corresponds to a, "*A leak of nuclear fuel material, etc. (excluding gaseous substances) inside a controlled zone as a result of a malfunction or other unforeseen circumstances at a commercial nuclear reactor facility,*" as noted in rule 18.11 of the Rules Pertaining to Safety and the Protection of Specified Nuclear Fuel Material at the TEPCO Fukushima Daiichi Nuclear Power Station Nuclear Reactor Facility.
- A detailed assessment of the amount of leaked radioactive substances found the volume to be approximately 1.5m^3 and sum of Cs-137 and Cs-134 to be approximately 6.6 billion Bq.
- The puddle on the steel plates was removed on February 7 and excavation of the soil into which the water may have seeped began on February 8. The measures for areas with risks of radioactive substance dispersion was completed on February 14. The removed soil are being stored in a dedicated storage container and managed in the same manner as rubbles.

【Supplement】 Schematic (for dose reduction work)







2. Timeline

February 5	14:17	• SARRY shutdown (planned)
	14:41	• Drain valves of SARRY filters and absorption towers opened. Caution tags attached
February 7	7:00	• Toolbox meeting and safety briefing
	8:07	• Work commences (contractor notifies the supervising group and shift that work can begin)
	8:15	• Lineup
	8:33	• filtrated water master valve opened • Started flowing filtrated water to the high temperature incinerator building
	8:36	• Pump started up in order to flush the system with filtrated water
	8:53	• Contractor worker discovers water leaking from the vent outlet on the outside of the east wall of the high temperature incinerator building • Contractor worker reports about the leak to the Emergency response HQ
	8:54	• Contractor worker notifies the emergency response center of the leak
	9:10	• Pump shutdown
	9:15	• filtrated water master valve closed
	9:16	• Shift workers inspect the site and confirm that the leak from the pipe has stopped
	9:37	• Area of the leak is cordoned off (access prohibited)
	10:50	• Smear test measurements of the leaked water reveals that it is system water mixed with filtrated water
	10:59	• It is confirmed that drainage channel K monitors near the area of the leak, monitoring posts and site boundary continuous dust monitor indicators do not show any significant fluctuations
	15:50	• It is deemed that in the event corresponds to a clause 18.11 event as noted in the 1F regulations and the government is notified
	20:00	• Recovery of the water on top of the steel plates concludes
February 8	16:50	• Soil recovery commences
February 14	–	• Completed measures for areas with high risks of radioactive substances dispersion

Note: Times are approximate

3. Assessment results for the amount of radioactivity that leaked

■ **Amount of the leak: Approx. 1.5m³** (Simplified assessment results from February 7, 2024: Approx. 5.5m³)

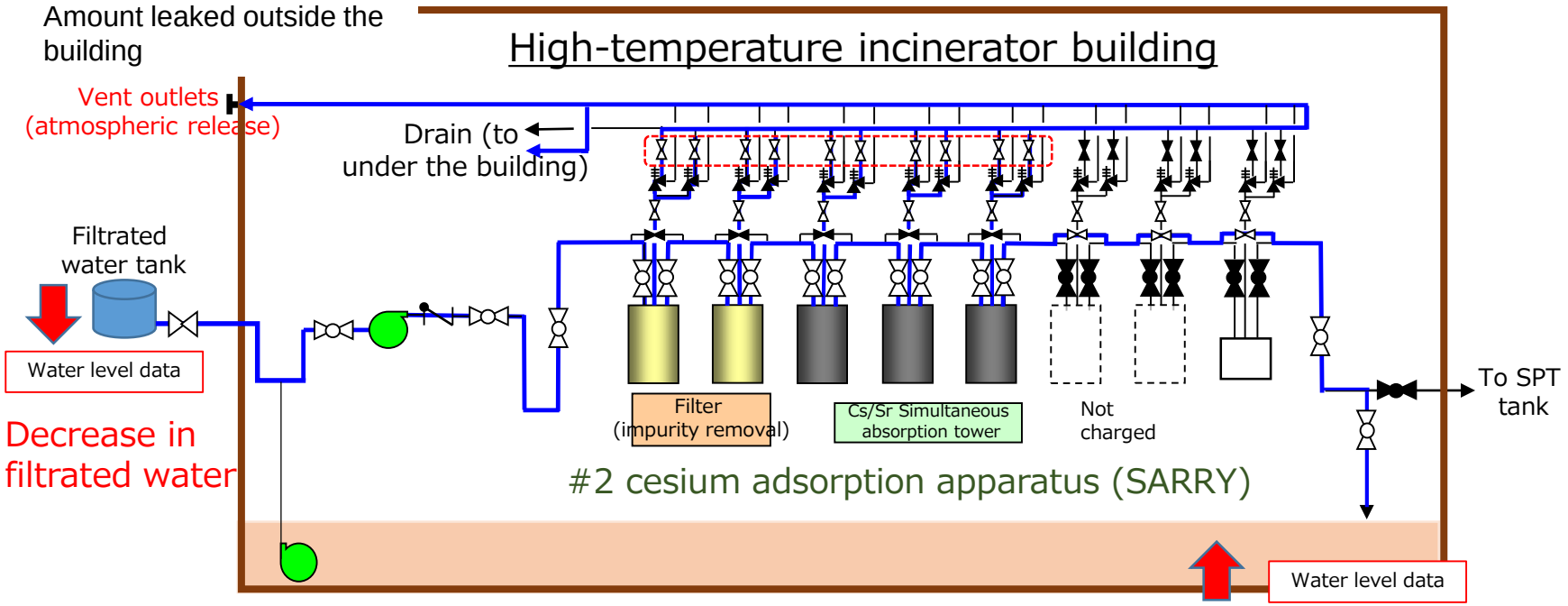
- Assessed using the primary radionuclides for which analysis records exist

Cs-134 : Approx. 1.1E+08Bq, Cs-137 : Approx. 6.5E+09Bq, Sb-125 : Approx. 8.5E+05Bq
Sr-90 : Approx. 4.2E+09Bq, H-3 : Approx. 2.2E+08Bq, Gross α: Approx. 2.2E+04Bq
(Simplified assessment results from February 7, 2024: Approx. 2.2E + 10 Bq: Gross γ (Cs-137 assessment))

※ The amount of radioactivity was calculated assuming that all water inside the system had been replaced by filtrated water
※ Levels requiring notification by law: Gross γ: 1.0E+8Bq

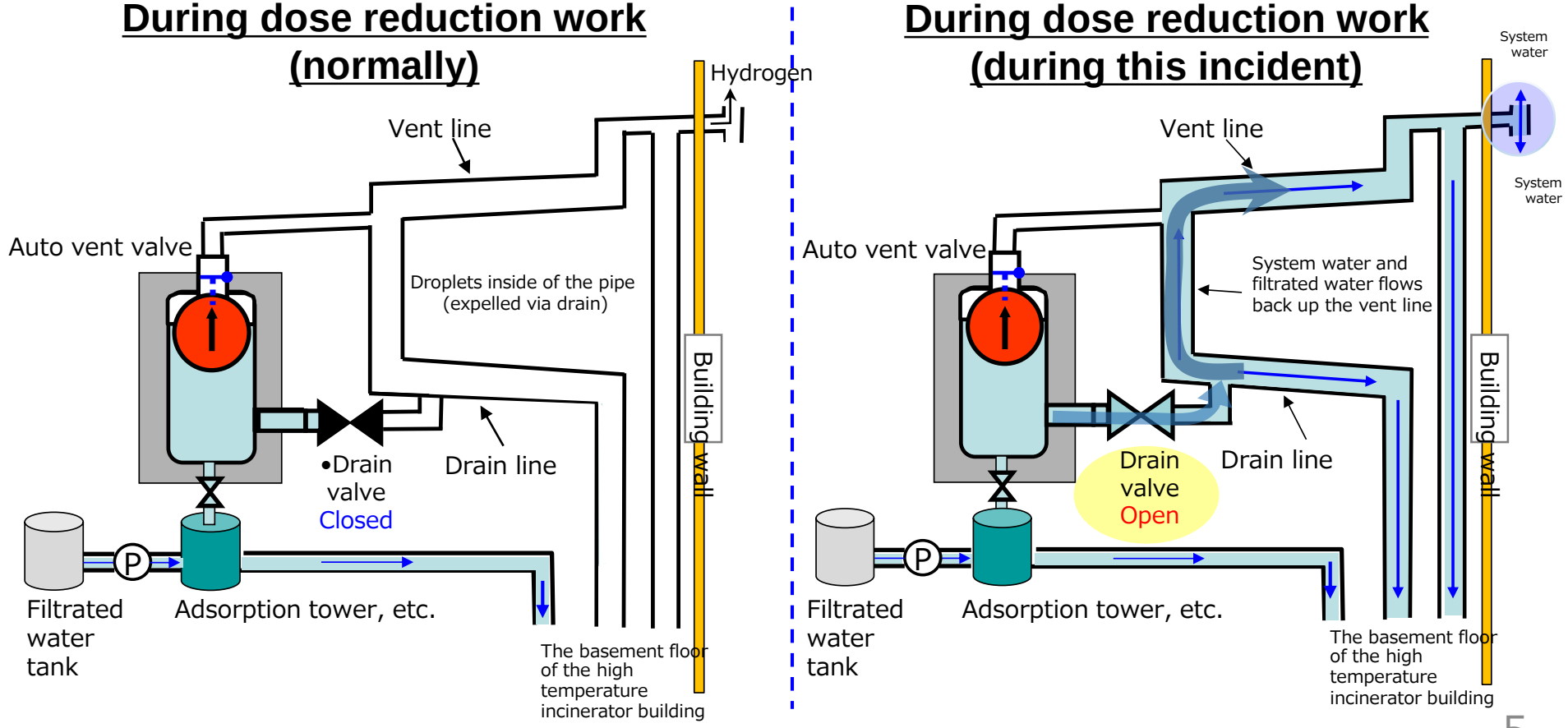
■ Assessment overview

- The amount of the leak was assessed from the water level decrease of filtrated water and the water level increase in the high temperature incinerator building. The amount of filtrated water used was closely investigated and the amount used for tasks other than the aforementioned task (approximately 4m³) was subtracted from the amount of decrease when the leak occurred as calculated during the simplified assessment (4 m³ subtracted from approximately 17.6m³ = 13.6m³).
- The amount of radioactivity was calculated from the radioactivity concentration of the system water and the amount of the leak. Design schematics were used to closely examine the amount of water inside the containers, such as the adsorption apparatus, etc., and subtract from the amount of system water used during the simplified assessment (reduced from approx. 9.12m³ to approx. 8.15m³)



4. Cause

- Dose reduction work to reduce dose prior to valve inspection was implemented with the filter and adsorption tower drain valves (10 valves in total) open.
- Since the drain valves were open, system water flowed into the drain lines.
- After flowing through the drain lines, the system water that couldn't drain out to the basement floor of the high-temperature incinerator building and flowed back up the vent line and leaked outside the building through the vent outlet.



5. Problems (1/2)

① **Problems related to creation of procedure manuals**

- TEPCO's Maintenance Department was in charge of pre-task system configuration (*1). TEPCO's Maintenance Department created the procedure manuals for this task based on design schematics and check for errors in the operations/check procedures, but the procedure manuals were not consistent with field conditions. In particular, whereas the procedures reflecting actual field conditions should have noted to switch the aforementioned valves from "open" to "closed," the procedures that were used this time stated to check that the aforementioned valves were "closed."

(*1) System configuration: safety measures to isolate systems that will be worked on. (i.e. closing boundary valves, etc)

(Underlying factors)

- At TEPCO, in principle, system configuration prior to equipment maintenance is handled by The Operations Department, which is acquainted with equipment operation/status.
- However, since the site became a high-dose environment and work volume greatly increased in the wake of the accident at the Fukushima Daiichi Nuclear Power Station, it is necessary to limit operator's exposure dose. Therefore, even though the aforementioned basic rule exists, the Maintenance Department (or the contractor) manage its own system configuration.
- As a result of this history, TEPCO's Maintenance Department was in charge of system configuration this time.
- When the SARRY system is in operation, the aforementioned valves are closed, and if maintenance work (dose reduction work, etc.) is not performed immediately after shutdown, the valves are opened in order to prevent hydrogen from accumulating inside the adsorption apparatus, etc., and caution tags (*2) are attached to the valves.

(*2) Caution tags: Tags attached when isolating equipment or when operations differ from regular procedures

- TEPCO's Maintenance Department did not sufficiently ask the Operation Department about the updated field status and therefore was not able to create suitable procedure manuals (*3).
  - TEPCO's Operations Department checked the procedures to confirm that there are no errors with procedures itself, but did not think that the field condition of the aforementioned valves was different from what was noted in the procedures, and therefore did not convey the fact that the aforementioned valves were "open."

5. Problems (2/2)

② Field work-related problems

- The worker checking the valves follow the procedures and employed methods for preventing human error (*1) while checking the valves, however the worker only checked to see if the valve numbers match the procedures and overlooked that the valves were "closed."

(Underlying factors)

- The procedures note that the aforementioned valves should be checked to see if they are "closed" prior to performing dose reduction work.
- The aforementioned general contractor has regularly performed this task over the last several years and the work has always been commenced with the valves "closed."
- The worker in charge of checking procedures assumed from past experience that the aforementioned valves were closed and when reading through the procedures on the day prior to the task, told the worker in charge of checking the valves that the aforementioned valves had always been closed.

- As a result of their assumptions, both of these workers (the worker checking the procedures and the worker checking the valves) overlooked that the valves were not "closed," and did not check the caution tags. Furthermore, since the task is high dose work, the workers were aware of getting the task done quickly.

Valve open

Valve closed

(*1) Human performance tools (HPT): Basic behaviors and methods for preventing human error, such as pointing to equipment/switches, etc. when performing actions, and taking a pause before performing any actions, etc.

6．Countermeasures (1/3)

(1) TEPCO management-related countermeasures

In light of this incident, TEPCO's Operations Department shall be solely in charge of system configuration (*1) prior to performing any task that involves the handling of highly concentrated waste liquid containing radioactive substances (contaminated water treatment equipment, ALPS, etc.)

① TEPCO's Maintenance Department shall not only review equipment schematics, but shall also ascertain field conditions in a timely manner, create procedures, and request pre-task system configuration (*1) of the TEPCO Operations Department.

② TEPCO's Operation Department shall be solely in charge of system configuration (*1) prior to performing any task, and then shall pass that duty on to TEPCO's Maintenance Department.

③ TEPCO's Maintenance Department shall confirm the system configuration (*1) performed by TEPCO's Operations Department prior to performing any task.

(※1) System configuration: safety measures, such as closing boundary valves, etc., to isolate systems that will be worked on.

(2) TEPCO organization-related countermeasures

- We are planning to formulate a “Water Treatment Center” in order to construct a system that centrally manage from the design to the maintenance and operational planning of water treatment (implementation plan modification authorization application to be submitted).
- By assigning a Safety and Quality Officer in the “Water Treatment Center” (inviting an expert from outside the company is also being examined) that manages/integrates groups in charge of the design and maintenance of water treatment and specializes in water treatment facilities that have not existed at other nuclear power stations, we can further improve the safety and quality of all water treatment procedures.

6. Countermeasures (2/3)

(3) Contractor actions and TEPCO involvement

○ In light of this incident, we will make sure that field workers thoroughly understand the importance of equipment operations and confirming equipment status, and also thoroughly perform basic actions.

- The aforementioned contractor will take the following corrective actions. TEPCO confirms the status of the implementation:
  - Continually use this incident as a case study to learn the importance of basic actions.
  - Immediately implement HPT education to all workers operating equipment.
  - Department supervisors from the aforementioned company shall conduct patrols, etc., to supervise/provide guidance to work foreman/team leaders to check that they are in turn providing suitable instruction/guidance, and also check that basic actions are being performed.

- TEPCO shall continually educate the aforementioned contractor about the objective of equipment tasks and the mental approach that they should take to these tasks (the importance of confirming equipment operations/equipment status).
- TEPCO shall provide the same education to companies engaged in the operation of equipment used to handle highly concentrated waste liquid containing radioactive substances (contaminated water treatment facilities, ALPS, etc.) as part of lateral dissemination.
- In order to eliminate these types of assumptions, TEPCO shall serve as an instructor and accelerate/develop "safety culture (aiming to further improve safety)" training currently being implemented for station personnel and contractors.

○ At the Fukushima Daiichi Nuclear Power Station on February 15, TEPCO president directly asked contractors to "thoroughly perform basic actions and check the actual conditions of equipment in the field. Stop, think and ask if you notice something."

6. Countermeasures (3/3)

TEPCO

(4) Equipment-related countermeasures

As part of equipment improvements, the current vent outlet that leads directly to the outside shall be reconfigured so that even if a leak like this occurs again the water will be expelled inside the controlled area inside the building, and an additional air vent shall be installed to prevent the accumulation of hydrogen.

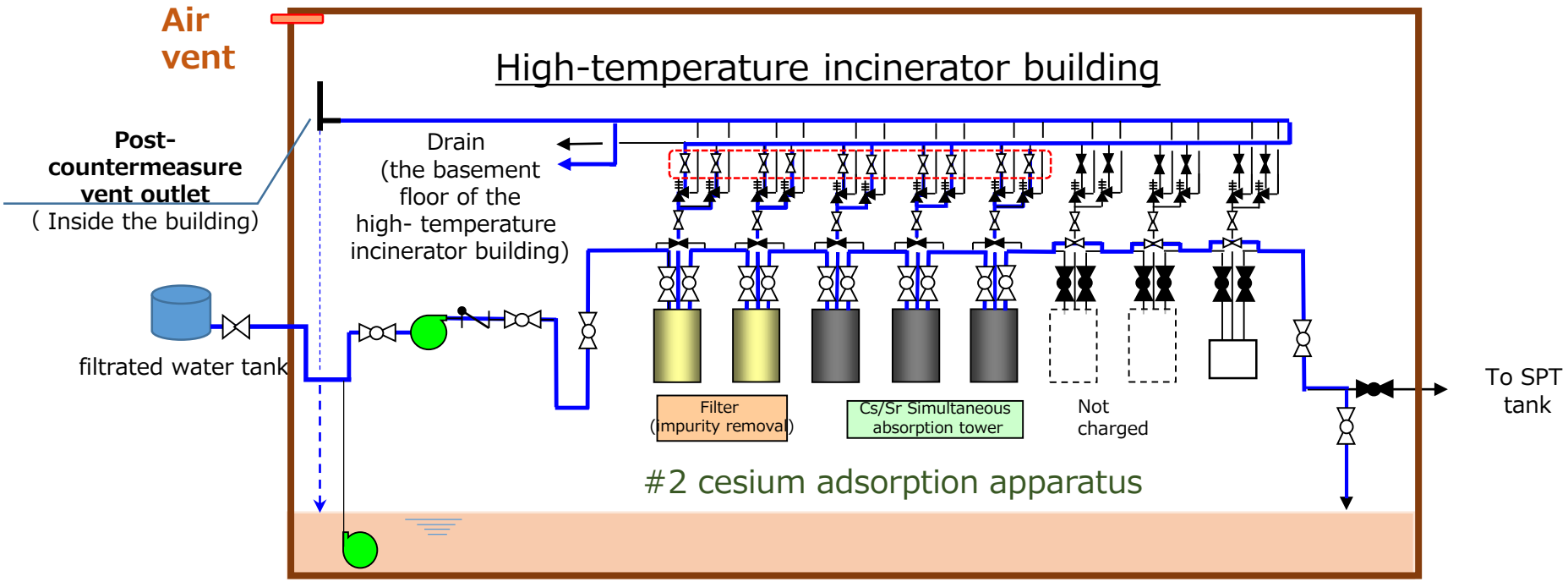
The Nuclear Safety Oversight Office (external experts will be invited), which is under the direct supervision of the president, will carefully examine the effectiveness of these recurrence prevention measures.

【Supplement】 Concept diagram for equipment improvements

- In light of this incident we have deliberated equipment improvements. The following was considered during these deliberations.
  - Preventing leaks of highly concentrated liquid radioactive substances outside buildings
  - Satisfying the specification requirements of existing equipment (preventing hydrogen generated inside absorption towers during shutdown from accumulating)

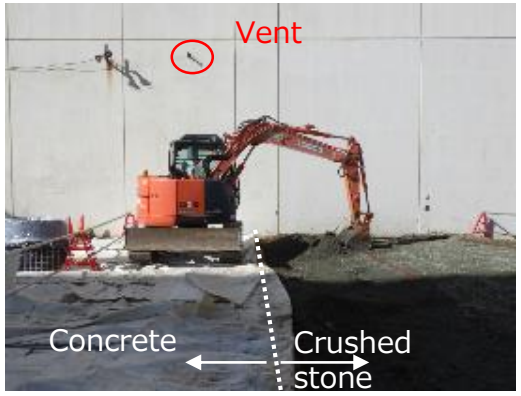
Permanent countermeasures (concept)

- ✓ Cut a part of the vent line so that the vent outlet is inside the building.
- ✓ Install an air vent in the wall that can release hydrogen into the air outside the building to prevent hydrogen from accumulating inside the building now that the vent exhaust outlet is inside.

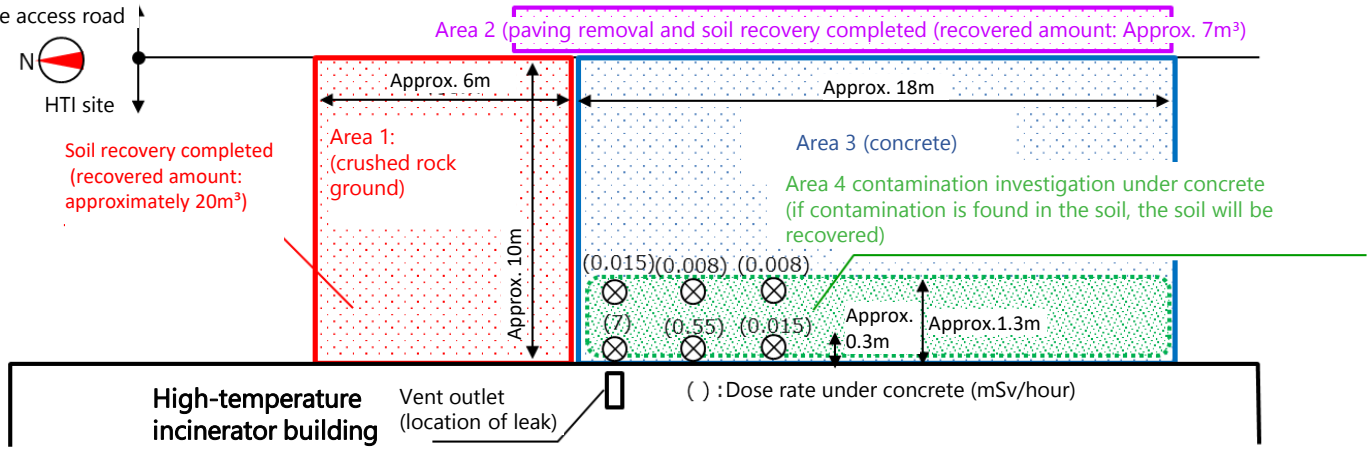


7. Implementation status of countermeasures to prevent the spread of contamination

- ✓ Soil recovery commenced on February 8. The work is carefully being conducted to avoid damaging buried equipment, prevent the dispersion of dust in conjunction with recovery work, and limit worker exposure (protective covers, etc., are being used to reduce the risk of dispersing leaked radioactive substances).
- ✓ Soil will be recovered until the ground surface dose rate ※ is lowered to below 0.020mSv (equal to background in the surrounding area on average.)
  - The work in areas 1~3 has been completed thereby eliminating the highly urgent risk of dispersing radioactive substances.
  - Core samples taken from underneath the concrete directly underneath leak area 4 revealed soil dose rate to be 7 mSv/hour, so contamination investigation of the ground underneath the concrete and soil recovery is being implemented. They shall continue until we confirmed that the ground surface dose rate* is below 0.020 mSv/hour on average.

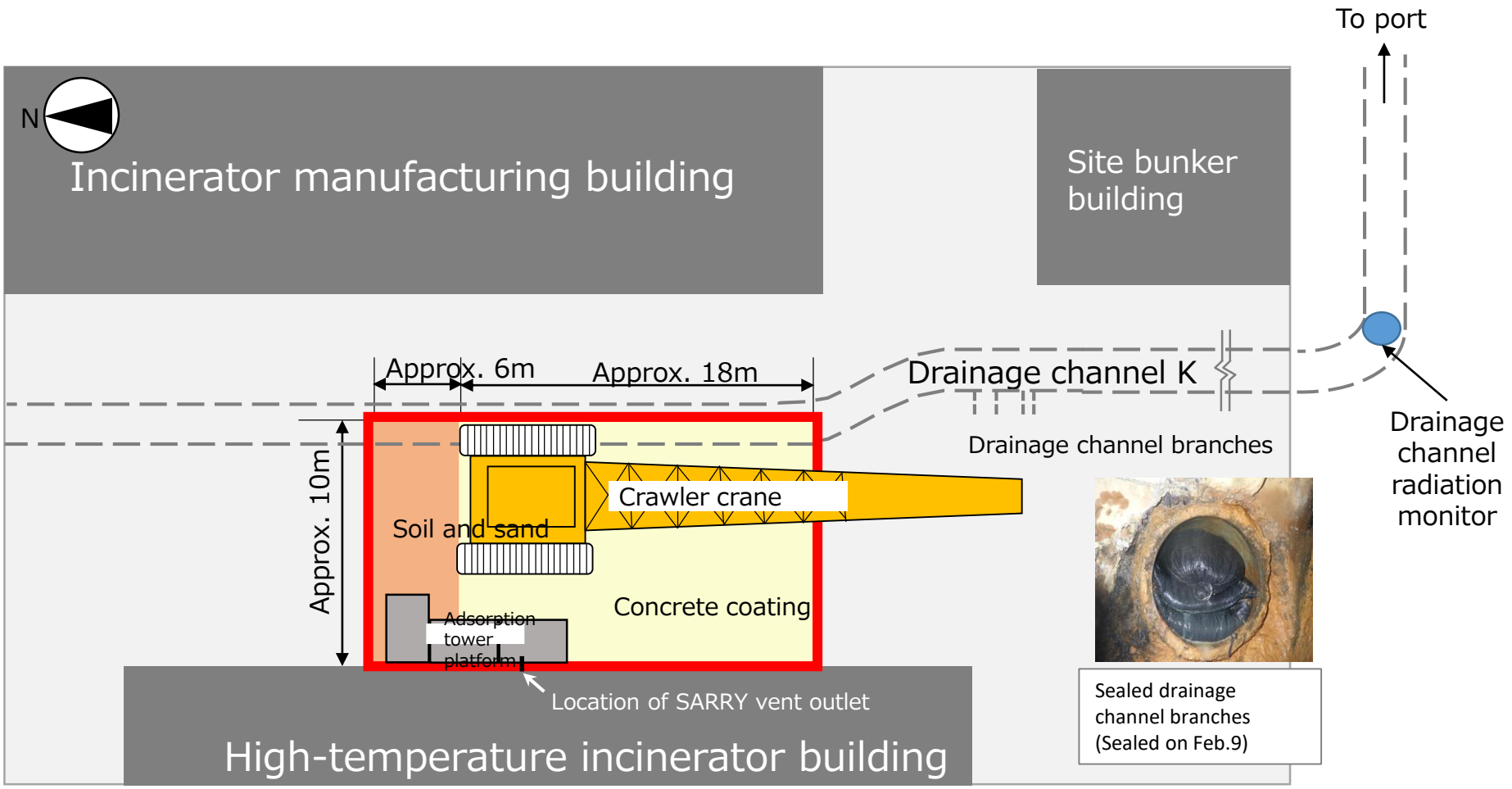


※70μm dose equivalent rate

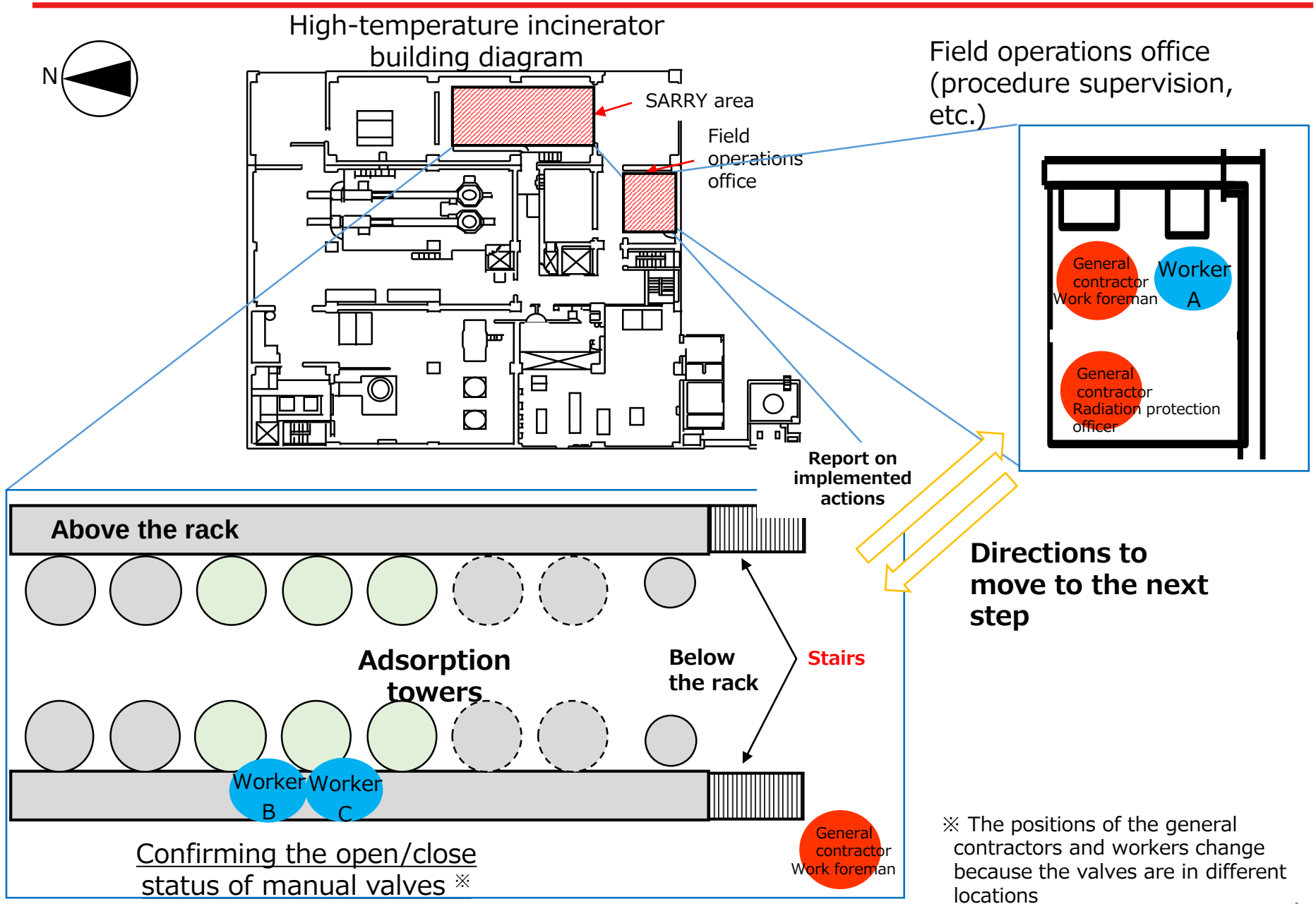


		2/8 (Thurs)	2/9 (Fri)	2/10 (Sat)	2/11 (Sun)	2/12 (Mon)	2/13 (Tues)	2/14 (Wed)	2/15 (Thurs)	2/16 (Fri)	2/17 (Sat)	2/18 (Sun)	2/19 (Mon)
Handling of the highly urgent risk of dispersing radioactive substances	Area 1 soil recovery	(Volume of recovered soil: Approx. 20m³)											
	Area 2 paving removal and soil recovery	(Volume of recovered soil: Approx. 7m³)											
	Area 3 coating												
Measures to be taken until countermeasures to prevent the spread of contamination are completed	Area 4 contamination investigation and soil recovery	Schedule may be extended depending on the results of the contamination investigation											

【Supplement】 Implementation status of countermeasures to prevent the spread of contamination

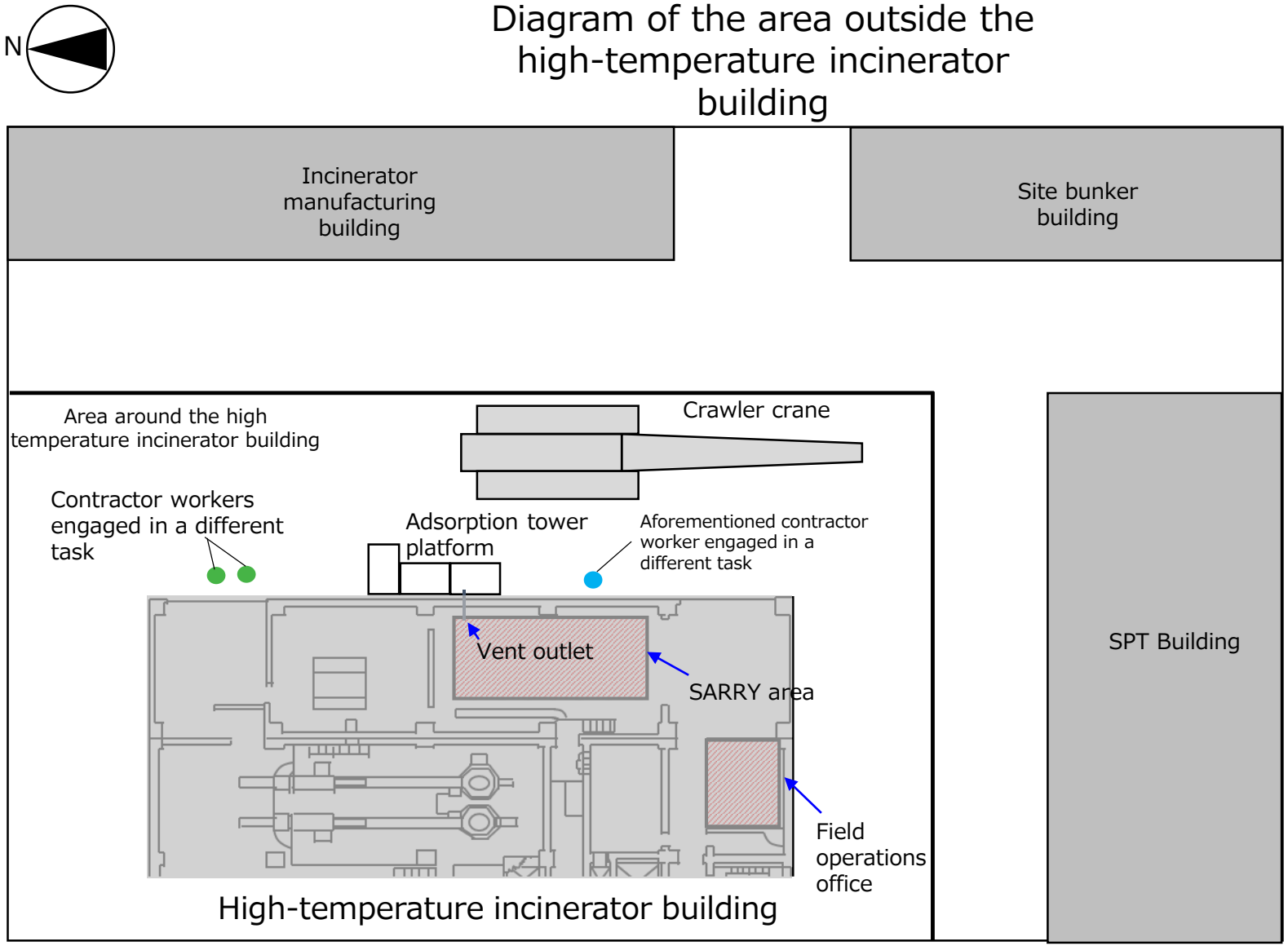


【 Reference 1 】 Diagram showing the position of workers (inside the building)



※ The positions of the general contractors and workers change because the valves are in different locations

【 Reference 2 】 Diagram showing the location of the workers that discovered the leak (outside the building)



【Reference 3】 Assessment details for the amount of leaked radioactivity

■ Calculations

（1）Amount that leaked outside the building during this incident

The difference in the amount of decrease in the filtrated water tank and the amount of increase of the water level inside the building from the time water started to flow into the high temperature incinerator building (8:33※1) until the time that flow stopped (9:15※1) was assessed to be **approx. 1.5m³**

- filtrated water tank decrease amount: Approx. 13.6m³ ※2
- High temperature incinerator building water level increase: Approx. 12.1m³ ※3

※1: Times determined from flowmeter "stagnant water transfer volume" (adsorption tower outlet) indicator

※2: filtrated water that was being used for other tasks (approx. 4m³) at around the same time the incident occurred was subtracted from the amount of decrease in the tanks (approx. 17.6m³

※3: The water level in the high temperature incinerator building rose approximately 9mm

（2）Recent radioactivity levels within the system

Assessed by multiplying recent radioactive concentration analysis results by cubic volume of adsorption towers and pipes in the system

- System cubic volume: Approx. 8.15m³※3 （#2 cesium adsorption apparatus system volume）
- Radioactivity concentration: Recent radionuclide concentration analysis results for #2 cesium adsorption apparatus
- Amount of radioactivity: **Cs-134: Approx. 9.576E+08Bq, Cs-137: Approx. 5.916E+10Bq, Sb-125: Approx. 7.710E+06Bq Sr-90: Approx. 3.790E+10Bq, H-3: Approx. 1.980E+09Bq, Gross α: Approx. 2.036E+05Bq**

※4： Detailed assessment using the volume of water inside vessels, such as the adsorption towers, etc., which was calculated approximately 9.12 m3 during the simplified assessment (February 7, 2024)

■ **Amount of radioactivity that leaked outside the building** (The amount of radioactivity was calculated assuming that "all of system water was replaced by filtrated water")

The amount of radioactivity that leaked outside the building was calculated by multiplying (1) the amount of leakage rate outside the building by (2) the amount of radioactivity inside the system

・**Cs-134**	**Approx. 1.056E+08Bq** =	（1）Approx. 1.5m³/Approx. 13.6m³ ※5	×（2）Approx. 9.576E+08Bq
・**Cs-137**	**Approx. 6.525E+09Bq** =		×（2）Approx. 5.916E+10Bq
・**Sb-125**	**Approx. 8.504E+05Bq** =		×（2）Approx. 7.710E+06Bq
・**Sr-90**	**Approx. 4.180E+09Bq** =		×（2）Approx. 3.790E+10Bq
・**H-3**	**Approx. 2.184E+08Bq** =		×（2）Approx. 1.980E+09Bq
・**Gross α**	**Approx. 2.246E+04Bq** =		×（2）Approx. 2.036E+05Bq

※5： The percentage of the volume of filtrated water tank decrease that leaked outside the building