Status of investigation on estimating situation of cores and containment vessels

1. Introduction

The conditions of Unit-1 and Unit-3 containment vessels (PCVs), and the situation of damaged and fallen fuel were estimated, at a technical workshop held on November 30th, 2011, based on comprehensive evaluation of then-available knowledge, such as temperature changes, etc. due to water injection by the core spray systems. The workshop (organized by the former Nuclear Industry and Safety Agency) was for estimating the conditions of core damage at Unit-1 to Unit-3 of the Fukushima Daiichi Nuclear Power Station.

The latest illustrations for the estimated core and in-containment conditions incorporating new knowledge obtained thereafter by field investigations, etc., are summarized in Figures 1-1 to 1-3. The information added to the estimated illustrations as of November 30th, 2011, is summarized in the following chapters.

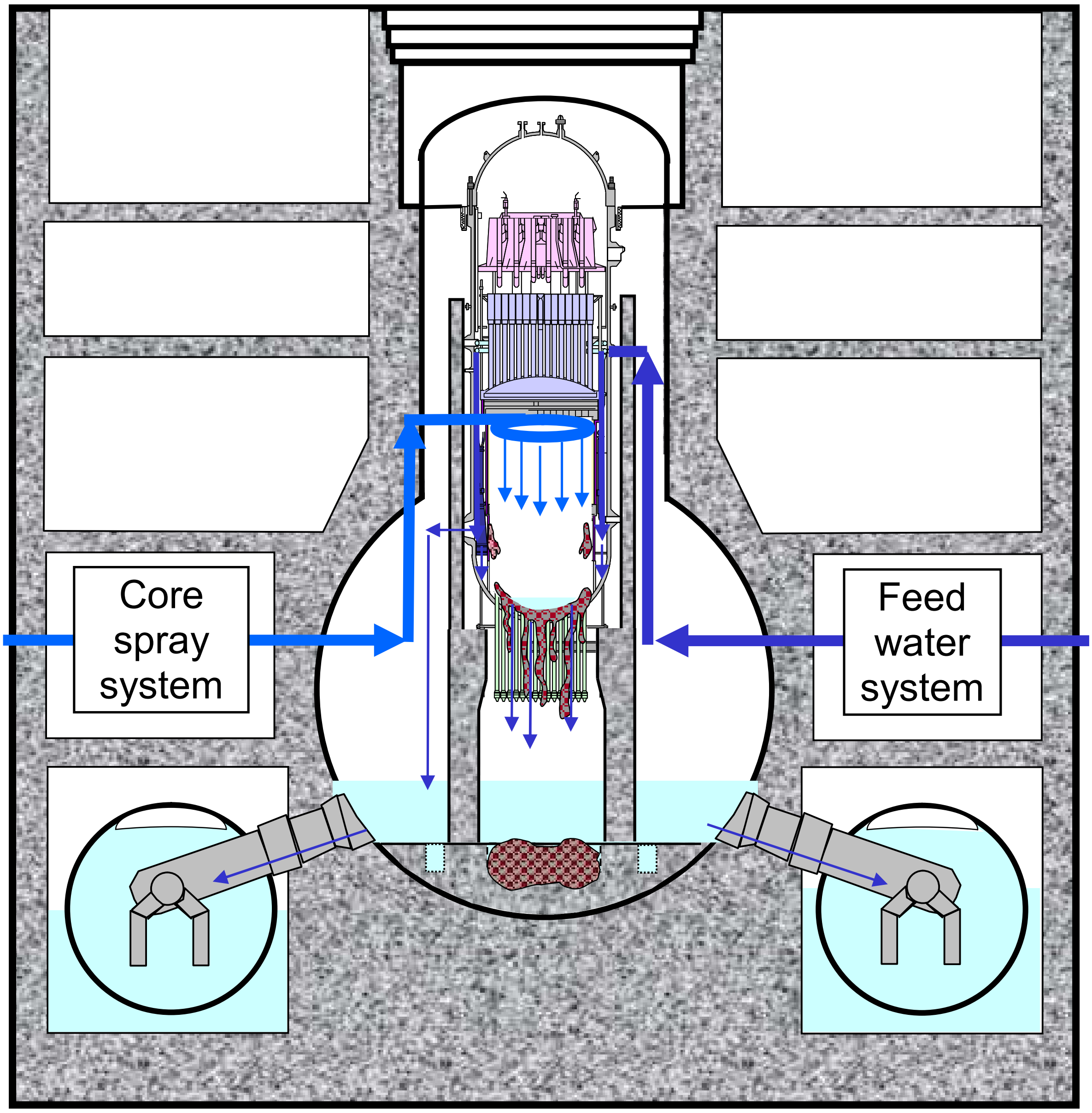


Figure 1-1　Estimated conditions of the core and PCV of Unit-1

(Note) Estimated conditions of the core and PCV are not updated from the previous report. The illustration does not accurately represent a quantitative image for the size, etc. of debris

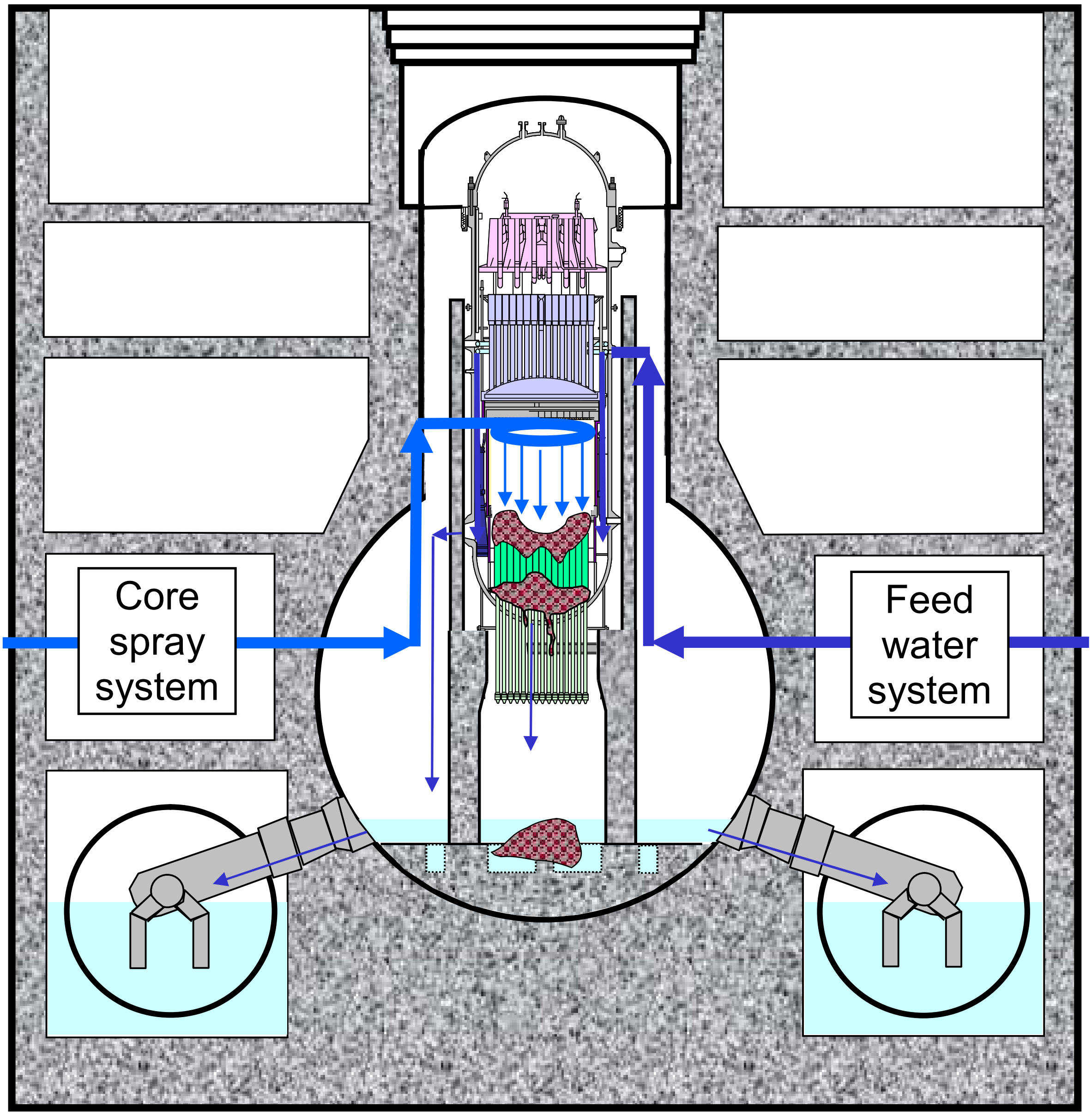


Figure 1-2 Estimated conditions of the core and PCV of Unit-2

(Note) Estimated conditions of the core and PCV are not updated from the previous report. The illustration does not accurately represent a quantitative image for the size, etc. of debris

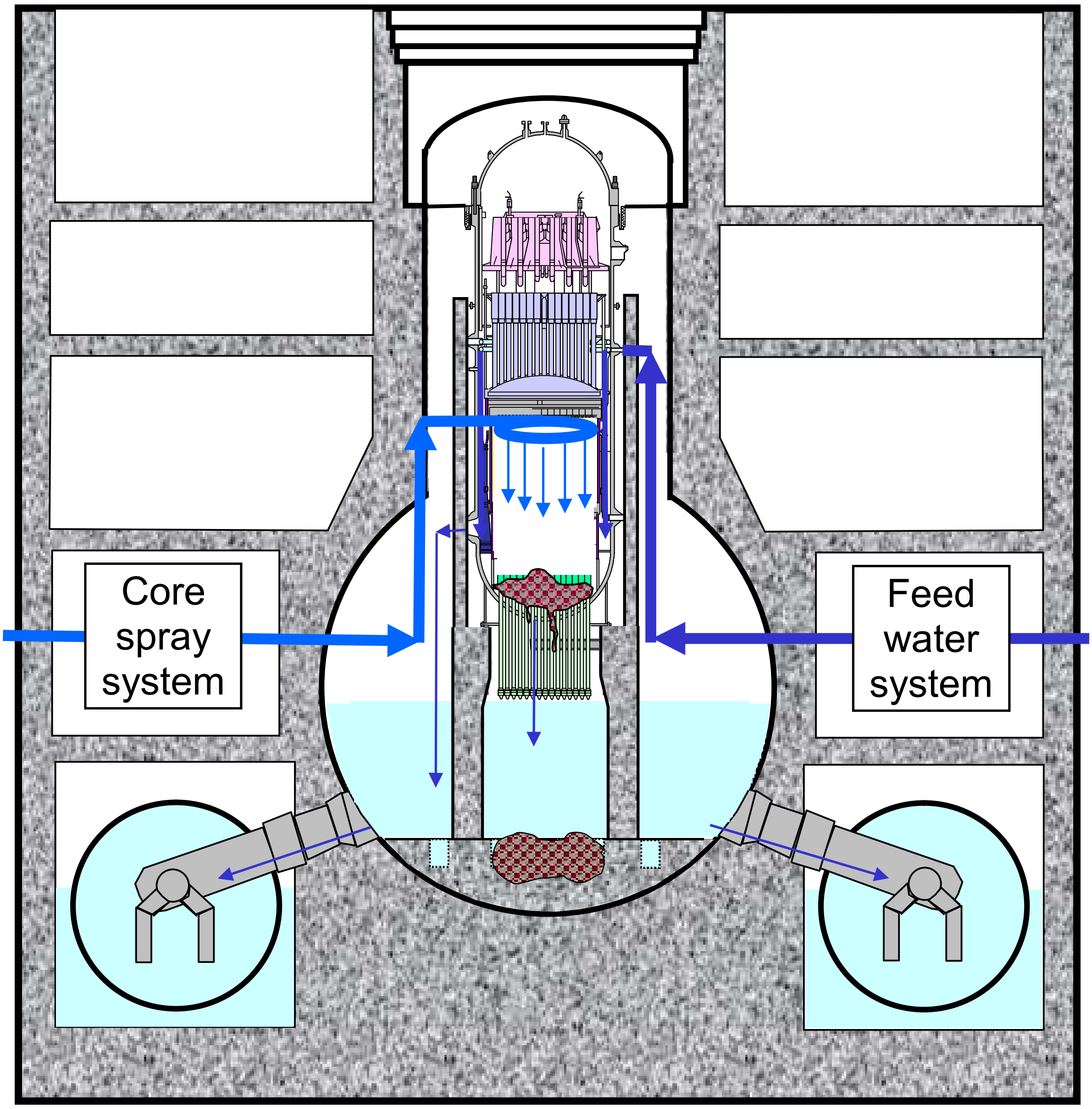


Figure 1-3　Estimated conditions of the core and PCV of Unit-3

(Note) The fallen debris on the PCV pedestal was shown larger this time, incorporating the analysis results of the case that sufficient water injection to the reactor had not been possible before the operator manually stopped the HPCI. The illustration does not accurately represent a quantitative image for the size, etc. of debris.

2. Conditions of Unit-1 core and PCV

(1) In-containment water level measured

In October 2012, an investigation was conducted into the status of the PCV of Unit-1, when photos were taken by cameras, the level of water retained in the PCV was confirmed, dose rates and temperatures were measured, and retained water was sampled and analyzed [1] by inserting survey devices into the containment through a hole dug at the PCV penetration (X-100B, on the first floor of the reactor building).

The level of water retained was measured by lowering the CCD camera cable down to the water surface through the grating above in the PCV. The water level was found to be about 2.8m above the D/W floor (as of October 10th, 2012) (Figure 2-1).

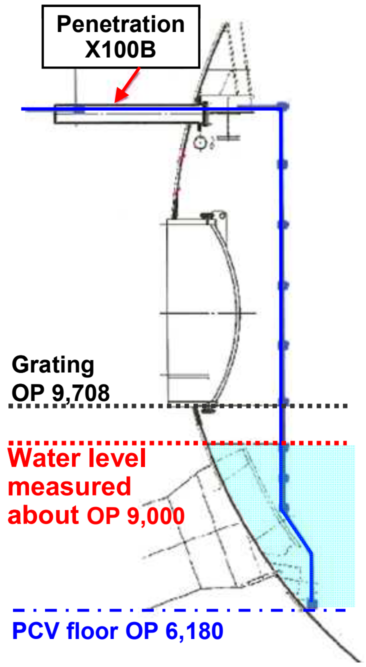


Figure 2-1 Measured level of water retained in Unit-1 PCV

(2) Test results of injecting nitrogen gas into the suppression chamber of Unit-1

In September 2012, a nitrogen gas injecting test was conducted into the suppression chamber (S/C), in which the theory was demonstrated that hydrogen gas and Kr-85 generated in the early stage of the accident and retained in the S/C upper space pushed down the S/C water level and were discharged to the D/W through the vacuum breakers. This helped to confirm that the S/C was currently almost filled with water (the level at around the lowest end of the vacuum breaker tube [2] (Figure 2-2).

This test was conducted with an intention to explain the phenomenon of the intermittent increase of hydrogen gas concentration and Kr-85 radioactivity measured by the containment gas control system of Unit-1 that has been seen since April 2012. This intermittent increase was assumed to occur in the following sequence: When the S/C water

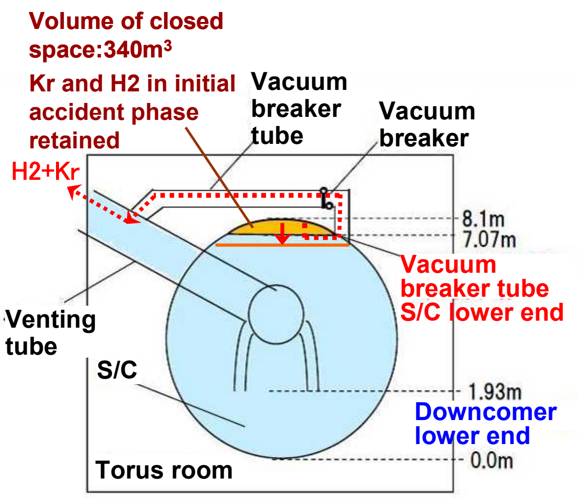


Figure 2-2 Closed space in gaseous phase inside S/C of Unit-1

[1] Handout document, 11th Steering Committee, Government – TEPCO Joint Board on Mid- and Long-term Response Policy, October 22, 2012

[2] Handout documents, 9th and 10th Steering Committees, Government – TEPCO Joint Board on Mid- and Long-term Response Policy, August 27 and September 24, 2012

level drops, residual gas left in the closed space in the upper S/C is discharged to the D/W through vacuum breakers, and then the S/C water level rises and stops the gas discharge. In this hypothesis, Kr-85 is understood to originate in the early phase of the accident, because Kr-85 is a long half-life fission product and its amount cannot be explained as being newly produced by spontaneous fission, etc.

In the test to verify the mechanism hypothesis, the S/C pressure (being monitored by the existing instrumentation) rose after the injection of nitrogen gas started into the S/C, the hydrogen gas concentration and Kr-85 radioactivity monitored by the containment gas control system started to increase, which decreased when nitrogen gas injection was halted. This is interpreted to be that the nitrogen gas injection pressurized the closed space of the S/C upper part, which lowered the S/C water level and formed a gas discharge channel to the D/W through the vacuum breakers, thus the retained gas in the space was discharged together to the D/W by the injected nitrogen gas.

Most of the hydrogen gas retained in the S/C has been purged by continuously injecting nitrogen gas into the S/C since October 2012. Further tests are now underway to verify a mechanism of hydrogen production in the S/C by water radiolysis.

(3) Investigation of the torus room of Unit-1

The torus room was investigated in February 2013, when photos were taken by cameras, dose rates and temperatures were measured, and retained water was sampled and analyzed by inserting thermometers, dosimeters and cameras through a ϕ200 hole dug on the northeast corner on the first floor of the reactor building [3].

Figure 2-3 Camera photo of an S/C vacuum breaker in the torus room of Unit-1

No water leaking position in the S/C has been located yet. At least, no leak was confirmed on the flange of one of the eight vacuum breakers, as far as the camera photos showed (Figure 2-3).

(4) Investigation of the situation at the bottom of the vent tubes in the torus room of Unit-1

In the torus room investigation in November 2013, a compact automated instrumentation boat, on which a camera and dose meters were mounted, was lowered into the torus room through a

[3] Handout document, Progress in preparations for decommissioning of Units-1 to 4 of the Fukushima Daiichi Nuclear Power Plant, Decommissioning Measures Steering Panel, March 7, 2013

510mm diameter hole drilled into the flooring of the first floor of the Unit 1 reactor building in the northwest corner. The boat was lowered to check visually for water leaks from the vent tube sleeve terminals, to check visually the condition of the sand cushion drain tubes, and to make dose measurements [4].

Camera imaging confirmed water leaks at the following locations (Figure 2-4).

- Vent tube X-5B (① in the figure): water flowing from the displaced sand cushion drain pipe*
- Vent tube X-5E (④ in the figure): water flowing down on the S/C surface with 2 streams around both sides of the vent tube

*Water leaks at ① were confirmed since the vinyl chloride pipe (connecting the sand cushion drain tube and drain funnel with an insertion-type joint) had been displaced. Water leaks could not be confirmed at locations ② to ⑧, since the drain tubes had not been displaced. The concrete seams (joints) below the sand cushion drain piping were observed to be wet all around on the concrete wall.

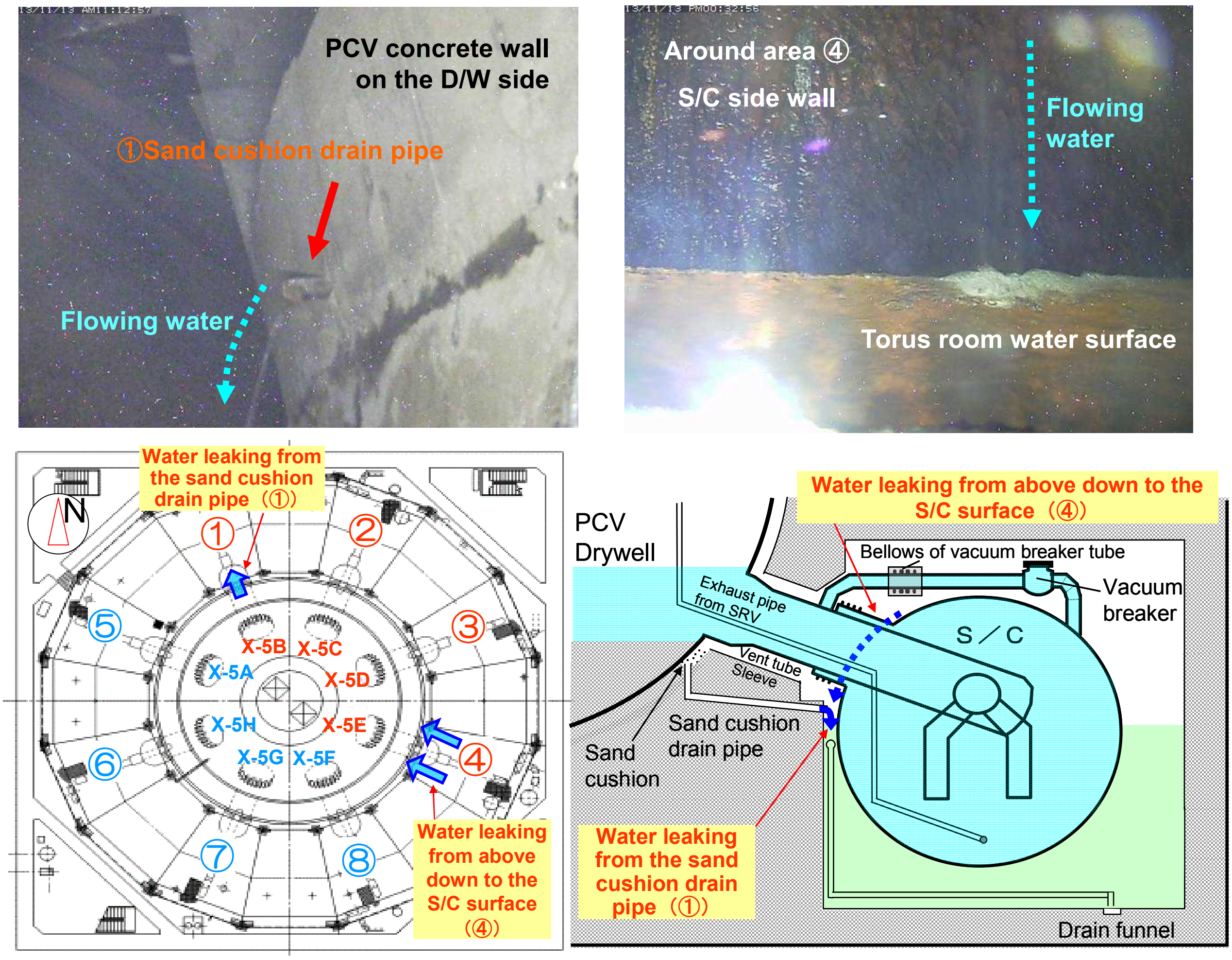


Figure 2-4 Camera images taken below the vent tubes in Unit 1 torus room (part)

[4] Handout document, Progress in preparations for decommissioning of Units 1 to 4 of the Fukushima Daiichi Nuclear Power Station, 10th Decommissioning Measures Steering Panel, November 28, 2013

Water leaks into the sand cushion occur only when water leaks directly from the drywell. The leakage is probably from a low position of the drywell below the water level (for example, the containment vessel shell, pipe penetrations, etc.). The low location of the water leaks in the drywell would indicate the possible influence of molten fuel that fell to the PCV bottom. This information is of critical significance in estimating the conditions of the core and PCV.

Meanwhile, the water leakage down to the S/C surface around both sides of the vent tube X-5E indicates the possibility of water leaks from the vacuum breaker tube (its bellows, for example) immediately above the vent tube. This elevation of the vacuum breaker tube is about the same level as that of the upper limit of PCV water level which was reached in an attempt to flood the PCV by increasing the amount of water injected in May 2011; where the PCV water level was calculated from the injected nitrogen gas pressure. The nitrogen gas pressure was stopped from changing at a specified level, which means the PCV water level was leveled off, i.e., an indication of leak hole existence at the level (Figure 2-5) [5].

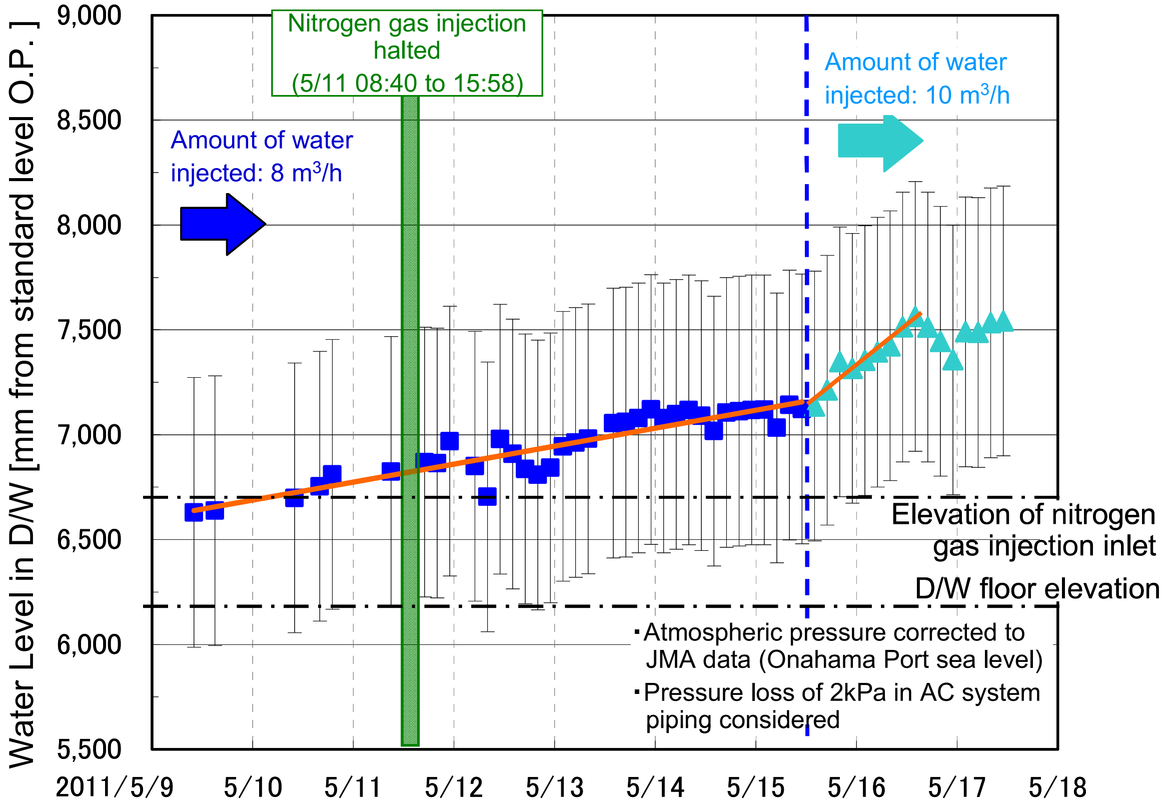


Figure 2-5　Estimated PCV water level changes during flooding operation of Unit 1 (May 2011)

The vertical distribution of radiation doses measured when lowering the instrumentation boat in November 2013 was similar to that measured in February 2013 (in the area surrounding the torus). Dose distribution along the boat traveling route was about 1 to 2 Sv/h, and the highest spots were in the southeast area (Figure 2-6).

[5] Handout document, Long-term cooling strategy team, Special Project, May 19, 2011

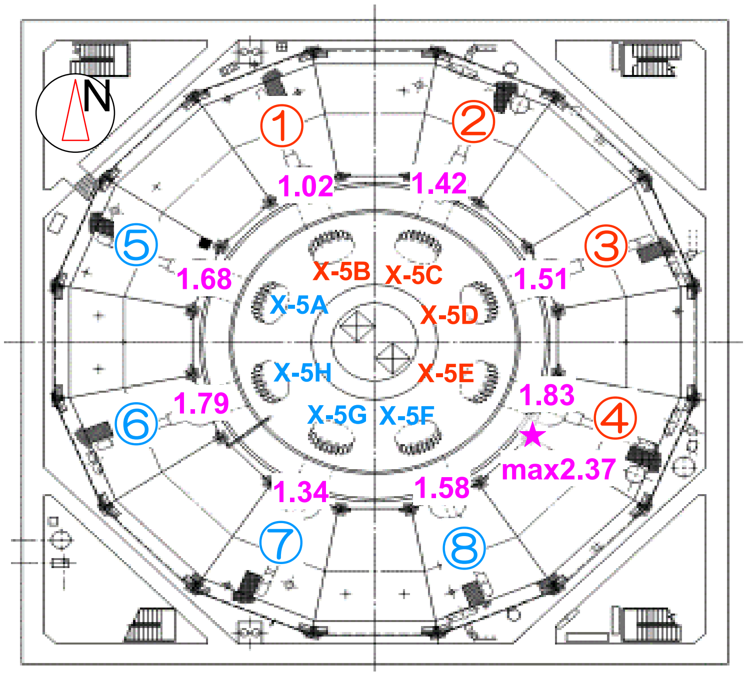


Figure 2-6 Dose distribution measured during the torus room investigation underneath vent tubes of Unit 1

In June 2011, steam blown from the pipe penetrations was witnessed at the southeast corner of the first floor of the reactor building. This would mean that radioactive materials carried by the steam were blown to the torus room after the accident and they deposited on the walls and structure surfaces there. The dose distribution in the torus room is considered to be the sum of doses due to these contamination sources. The estimated radiation dose levels on the water surface due to water–retained radionuclides (7.3×10^4 Bq/cm^3 of Cs-134 and 1.5×10^5 Bq/cm^3 of Cs-137, sampled on February 22, 2013) are about 100 mSv/h and not a dominant contributor to the 1 to 2 Sv/h dose measured [6].

In May 2014, survey instrumentation robot was introduced through a drilled hole in the northwest area of the first floor of the Unit1 reactor building to explore the S/C top area in order to locate the leak source near the vent tube X-5E, where leaking had been confirmed. By using the outer catwalk, the instrumentation robot made a camera survey around the vent tube X-5E, and the water leak was confirmed to be from the protective cover of the expansion joint on the vacuum breaker line. No leaks were noticed from the vacuum breaker valve, torus hatch, Shutdown cooling system (SHC) piping or Atmospheric control system (AC) piping (Figure 2-7) [7].

[6] Handout document: Consideration of dose measurement results in the torus room of Unit-1, 7th Meeting of Specific Nuclear Facilities Survey and Examination, March 29, 2013.

[7] Handout document: Consideration of dose measurement results in the torus room of Unit-1, 6th Meeting of Specific Nuclear Facilities Survey and Examination, May 29, 2014

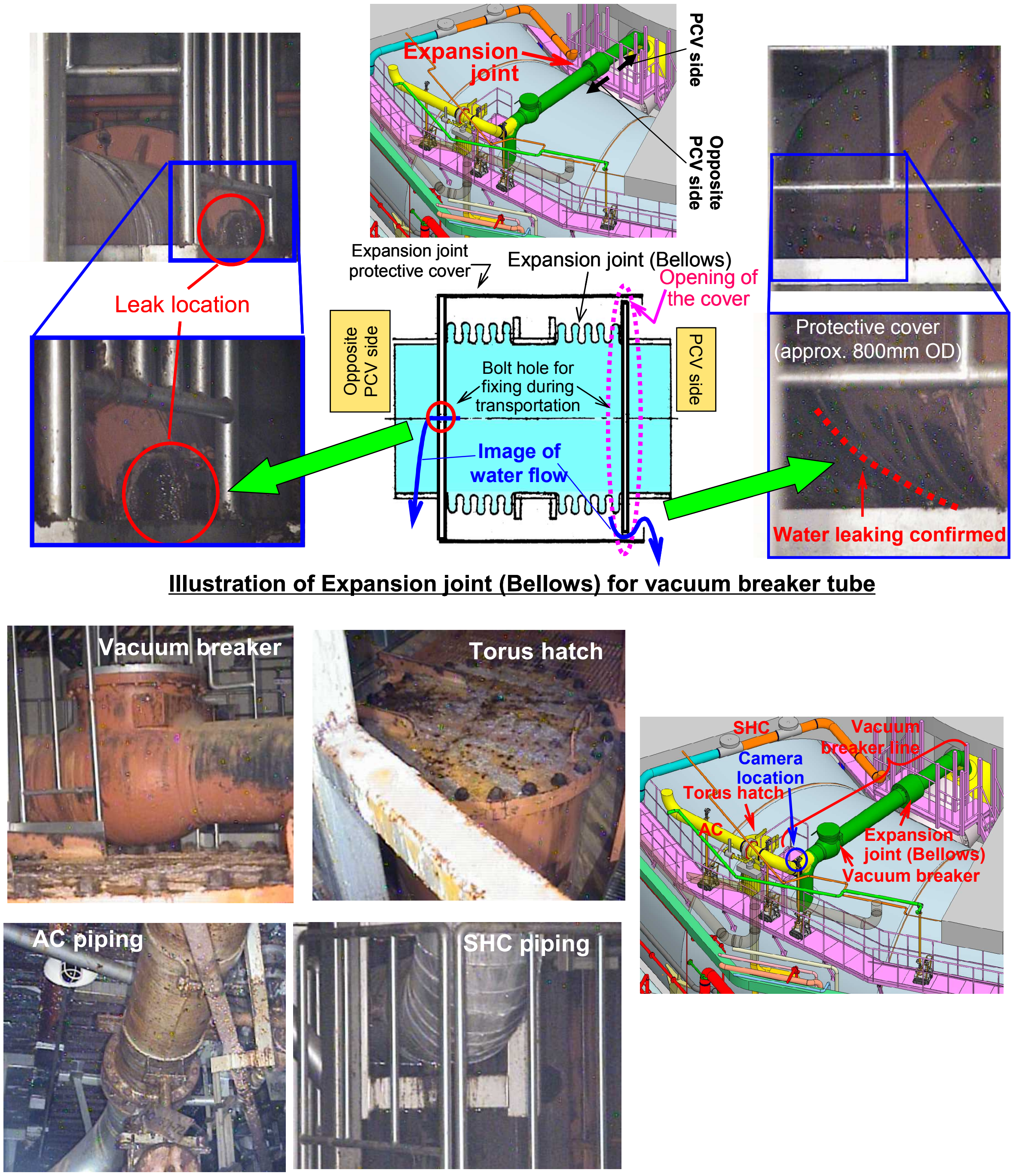


Figure 2-7　Camera images of Unit-1 S/C top area exploration (around vent tube X-5E) (Part)

(5) Contamination survey on the Unit-1 reactor building first floor

In December 2013, contamination was surveyed on the first floor of the Unit-1 reactor building by radiation dose measurements and gamma camera images taken using a robot. It was found that contamination was relatively high on the Atmospheric control system (AC) piping and Drywell humidity control system (DHC) piping (Figure 2-8) [8].

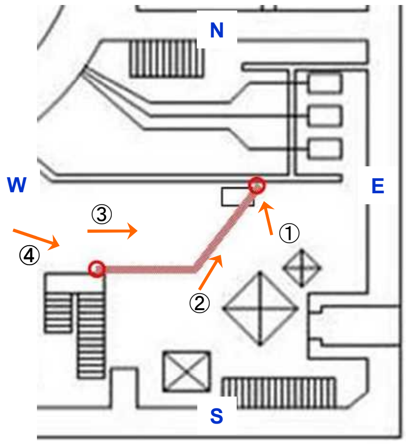


Figure 2. AC system piping route (about 2m elevation)

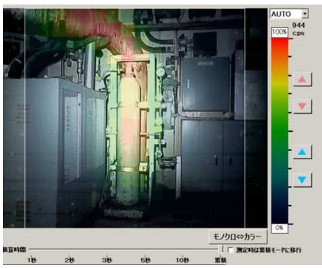


Figure 3. Photo from ①

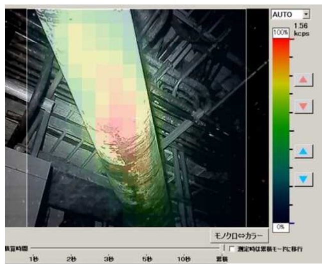


Figure 4. Photo from ②

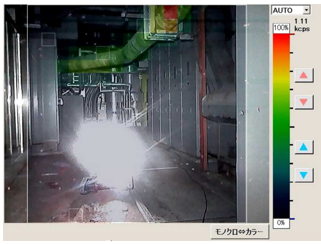


Figure 5. Photo from ③


Figure 6. Photo from ④

(Gamma camera image taken near the AC system piping in the reactor building 1st floor)

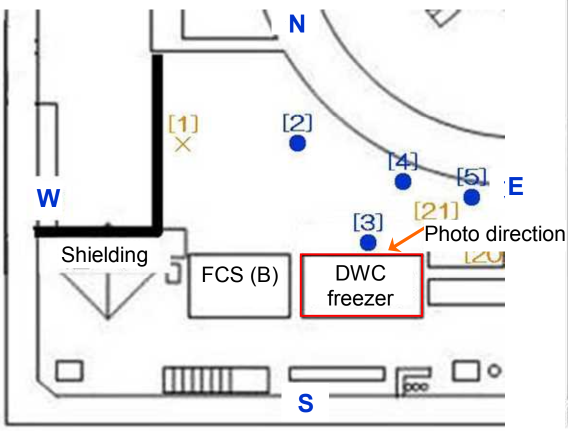


Figure 9. Layout

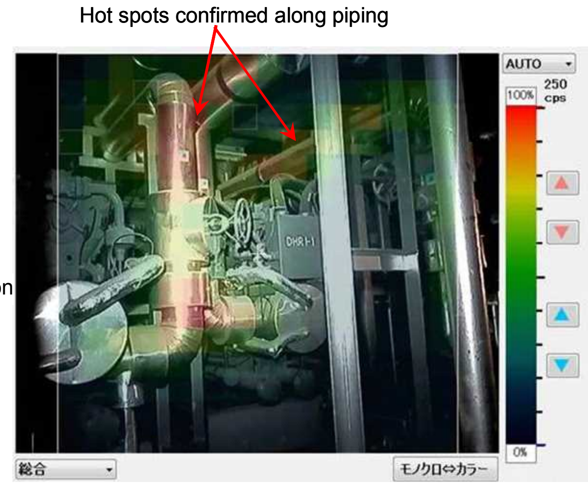


Figure 10. Gamma camera image taken near the DWC freezer

(Gamma camera image taken near the DWC system piping in the reactor building 1st floor)

Figure 2-8 Gamma camera images in the southern area of Unit 1 reactor building 1st Floor (part)

The AC piping is where the steam passed through when the wetwell (W/W) venting was carried out during the accident. Its high contamination is considered to be due to venting flows, and the situation was similar to that for the area near the standby gas treatment system (SGTS) train entrance room or near the SGTS piping connected to the main stack, where high dose rate had

[8] Handout document: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 2nd Decommissioning and Contaminated Water Response Team Joint Meeting, January 30, 2014

been already confirmed.

The DHC piping is connected to the Reactor building closed cooling water system (RCW), and therefore its high dose is considered to be due to the same mechanism as that of RCW piping, where high dose rate had been already confirmed.

(6) Investigation of the grating floor on the ground level outside the pedestal of Unit-1

The grating floor on the ground level outside the pedestal of Unit-1 was investigated from April 10th to 18th, 2015. A running robot machine was sent through the PCV penetration X-100B. The robot patrolled clock-wise and anti-clock-wise by about 180 degrees for investigating damaged conditions of existing structures and presence of obstacles. Figure 2-9 and Figure 2-10 present a part of the photos taken during the anti-clock-wise and clock-wise patrols, respectively. As seen in Figure 2-9, no big damage was recognized on the HVH (Heating Ventilating Handling unit), PLR piping, pedestal walls, PCV inner walls, etc., although fallen objects were noticed on the patrol path.

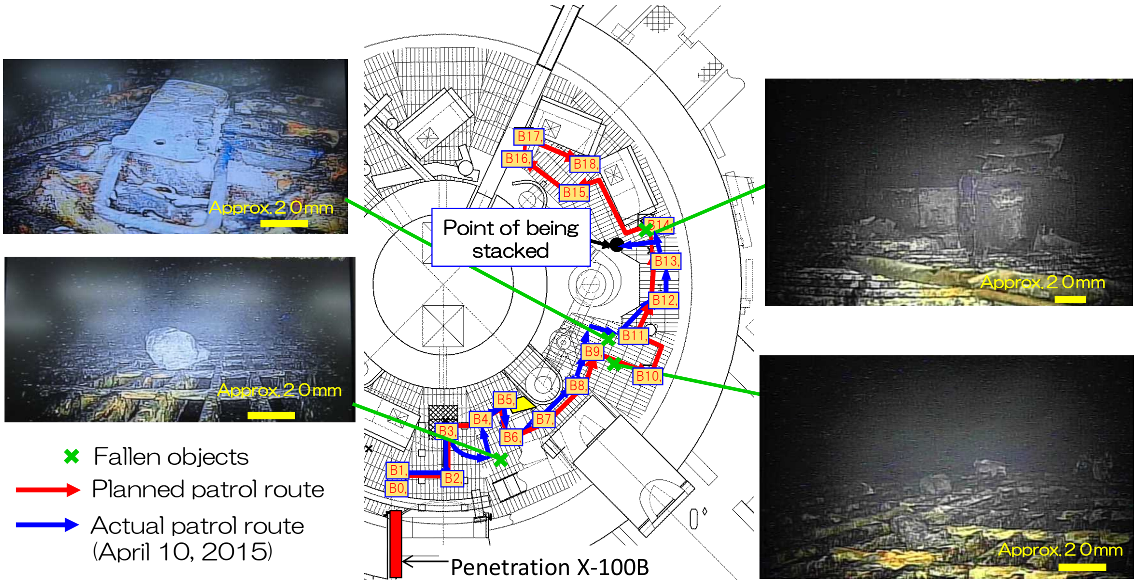


Figure 2-9 Photos taken during the anti-clock-wise patrol [9]

[9] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 17th Decommissioning and Contaminated Water Response Team Joint Meeting, April 30, 2015

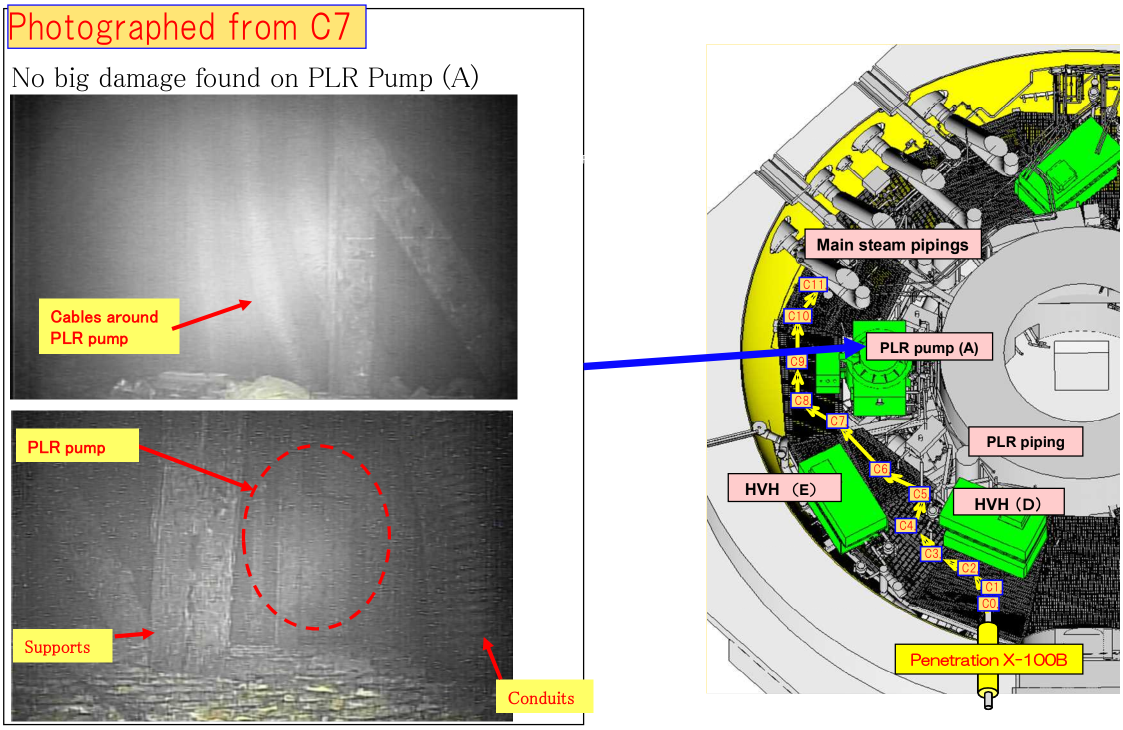


Figure 2-10 Photos taken during the clock-wise patrol [9]

(7) Investigation of Unit-1 using the muon tomography measurement device

A fluoroscope technology for nuclear reactors (transmission method) using muons is being developed jointly by the International Research Institute for Nuclear Decommissioning (IRID) and the High Energy Accelerator Research Organization (KEK) of Japan. The project is included in the "Development of detecting technologies of fuel debris in a nuclear reactor" under the "Project of Decommissioning and Contaminated Water Management in the FY2013 Supplementary Budget" sponsored by the Agency for Natural Resources and Energy (ANRE). The conditions inside the Unit-1 PCV were investigated based on the data collected during 96 days from February 9th to May 21st, 2015.

Figure 2-11 shows the predicted image of the reactor from the design (left) and the image of the actual reactor obtained by muon measurements for 96 days (right); both are images by a single muon device. The basic principle of measurements by the muon transmission method is the same with that of X-ray (Roentgen) photography. High density objects absorb more muons and are photographed in black. In the image of the reactor as designed with intact fuel, a black portion is recognized corresponding to the position of the core. In the image of the actual reactor, on the other hand, some recognizable equipment such as the spent fuel pool and isolation condensers are found, but there is no high density object (fuel) at the core position.

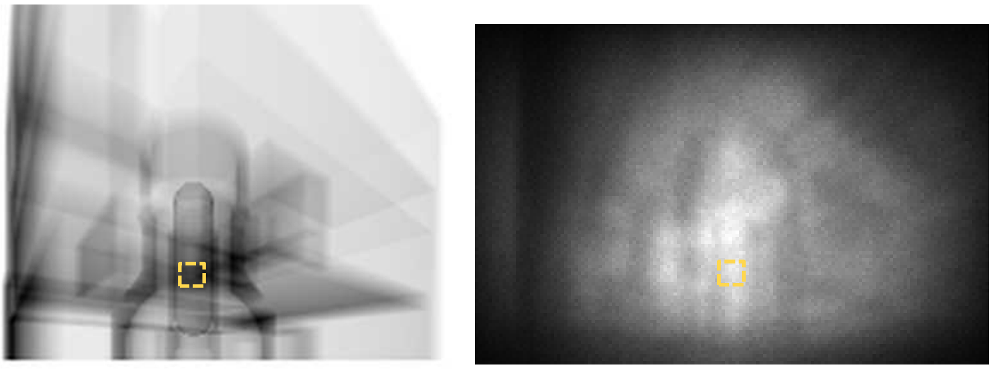


Figure 2-11 Muon image of the reactor predicted from the design (left) and that of the actual reactor based on measurements for 96 days (right)[10]
(dotted region corresponds to the original core position)

By combining data measured using two muon measurement devices, images can be restructured in three dimensions. Distribution maps of high density materials are shown in Figure 2-12 at different elevations of the reactor building (R/B). The red region on the distribution maps is where high density materials are detected by the two muon measurement devices at each elevation. High density materials are recognized at the spent fuel pool position, but not at the core position.

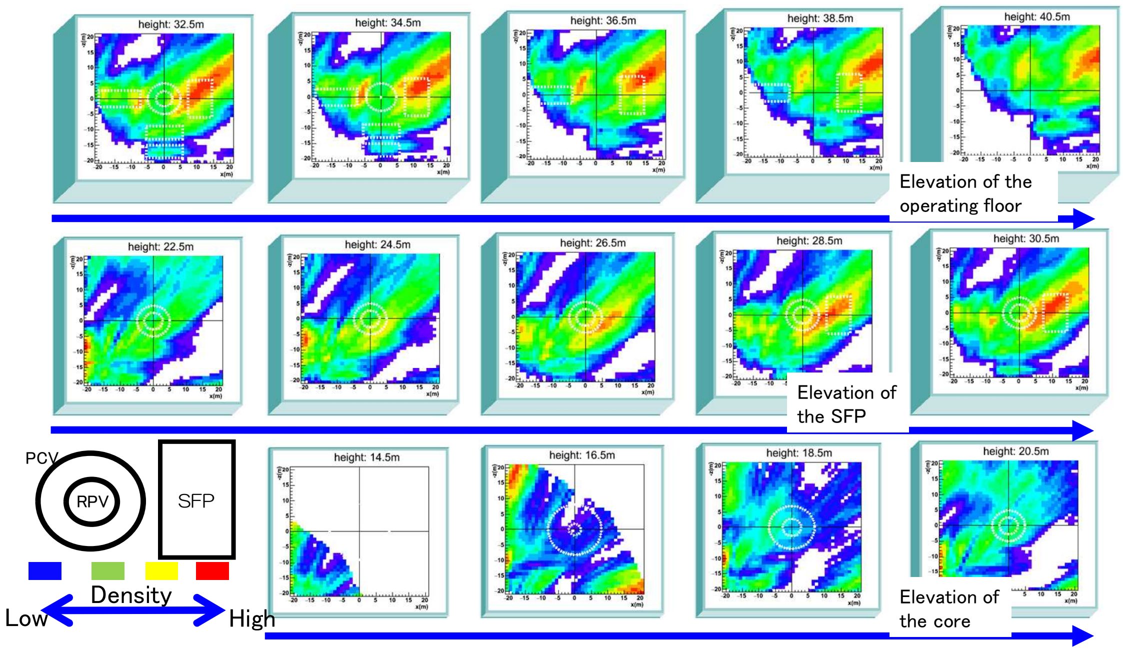


Figure 2-12 High density material distribution maps at three separate elevations

From these considerations, no fuel is thought to be left at the core position. This is consistent with the estimated conditions of the core and PCV previously announced by TEPCO.

[10] Handout document: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 18th Decommissioning and Contaminated Water Response Team Joint Meeting, May 28, 2015

(8) Investigation of the TIP room of Unit-1

The TIP (traversing in-core probe) room on the R/B ground floor was investigated from September 24th to October 2nd, 2015. This investigation was implemented to check feasibility of reducing the radiation dose near the PCV penetration X-6, stopping the water in the lower part of the PCV, repairing the PCV, etc.

Figure 2-13 presents the spatial air dose rates measured in the TIP room and Figure 2-14 shows a γ-camera photo taken there. A high radiation dose of above 100mSv/h was observed near the PCV penetrations, especially around X-31, -32 and -33, while on the turbine side behind the chamber shield the dose rate was as low as below 2mSv/h. The γ-camera photos located a radiation source near the penetrations X-31, -32 and -33 (Region 1 in Figure 2-14). No other outstanding radiation source was found in the room, including at the penetrations X-35A to -35D which were outside the view of the wide-angle lens camera (the area encircled by the broken line in Figure 2-14).

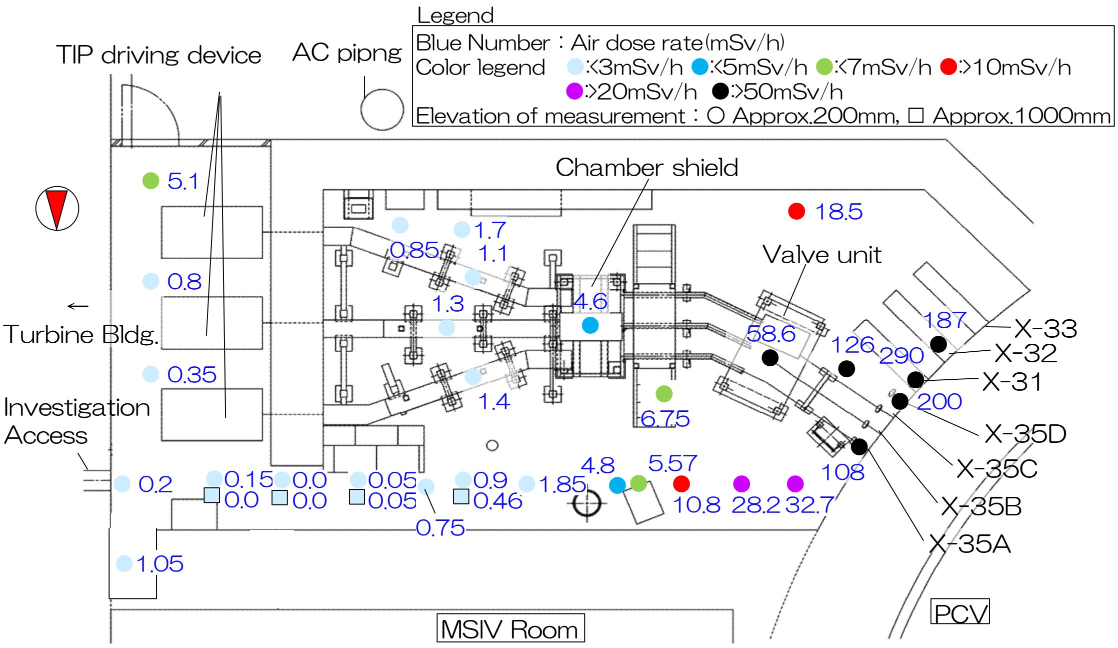


Figure 2-13 Air dose rates distribution measured in the TIP room [11]

[11] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 23rd Decommissioning and Contaminated Water Response Team Joint Meeting, October 29, 2015

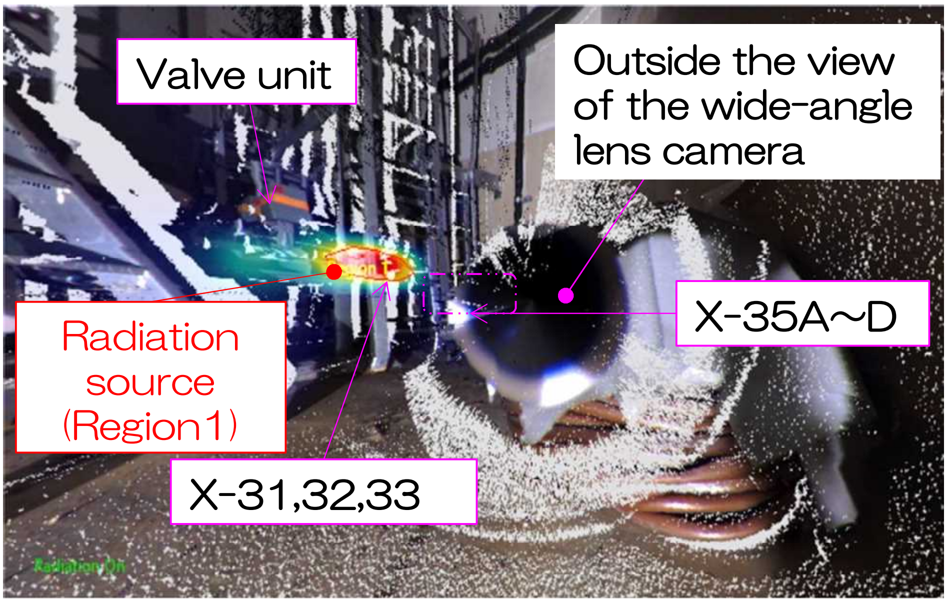


Figure 2-14 γ-camera photo taken in the TIP room [11]

Exterior appearances of PCV penetrations, piping and other objects in the TIP room were surveyed by an optical camera. Some brown-colored specks hinting at flow lines were noticed around PCV penetration X-35A (Figure 2-15). But, as mentioned above, no radiation source was noticed around the area of penetrations X-35A to X-35D. No other marks hinting at leaks were recognized at any places around the penetrations, piping and other objects in the TIP room including the penetrations X-31, -32 and -33.

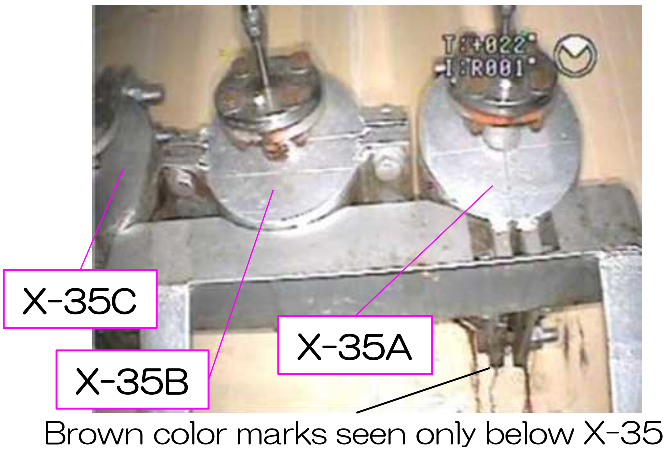


Figure 2-15 Optical camera photo taken at the penetration X-35 [11]

3. Conditions of Unit-2 core and the PCV

(1) In-containment water level measured

In March 2012, investigation was conducted into the PCV of Unit-2, when photos were taken by cameras, the level of water retained in the PCV was confirmed, and dose rates and temperatures were measured [12] by inserting survey devices into the PCV through a hole dug at the PCV penetration (X-53, on the first floor of the reactor building).

The level of water retained was confirmed to be about 60 cm above the D/W floor by the video image scope (as of March 26th, 2012) (Figure 3-1).

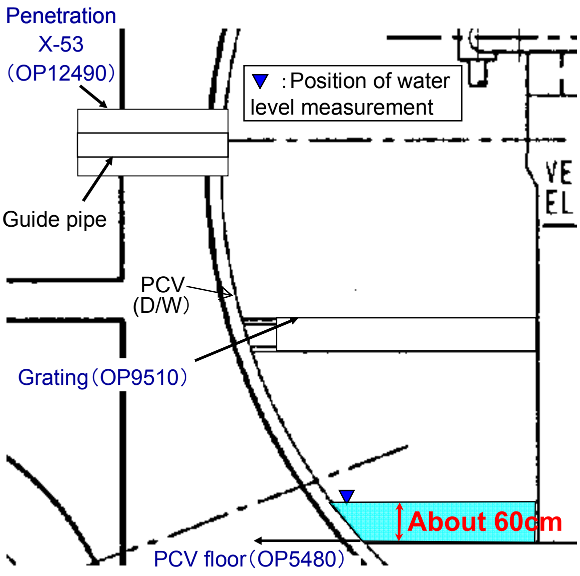


Figure 3-1 Measured level of retained water in Unit-2 PCV

(2) Survey results near the PCV pedestal opening of Unit-2

In July and August 2013, a survey was conducted inside the PCV of Unit-2, when instrumentation was introduced through the PCV piping penetration X-53 (reactor building first floor) to take camera images and make dose and temperature measurements in the vicinity of the control rod drive mechanism (CRD) replacement railand pedestal opening (Figure 3-2) [13].

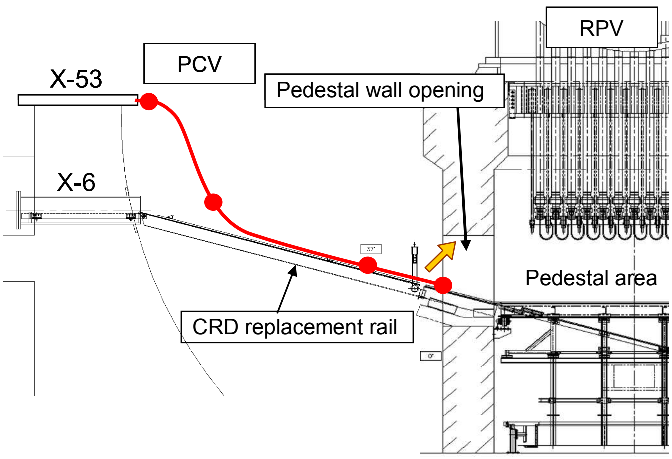


Figure 3-2 Survey areas inside Unit-2

Camera images were taken at the pedestal opening into its inside and after photo processing for noise and contrast, they confirmed the position of the control rod position indicator probe (PIP) cables in the upper part of the pedestal opening, but no clear information was obtained regarding what was in the lower part inside the pedestal (Figure 3-3).

Dosimeters measured the dose rates as far as the top of the CRD replacement rails. The values were about 45 – 80 Sv/h. As supplementary information, dose rates were estimated from the camera image noises; they were about 30 Sv/h near the landing point in replacement rail and

[12] "Results of PCV investigation and plan for identifying leak path", Technical workshop for Fukushima Daiichi accident, July 24, 2012
[13] Handout document, Progress in preparations for decommissioning of Units 1 to 4 of the Fukushima Daiichi Nuclear Power Station, 7th Decommissioning Measures Steering Panel, August 28, 2013

about 36 Sv/h near the pedestal opening. No clear indication was obtained about gaining access to fuel debris, even via the pedestal opening on the CRD replacement rail because access to fuel debris will result in rapid dose rate increase.

(Reference information)
Pedestal opening of Unit-5

Figure 3-3 Photos inside the PCV pedestal taken at the pedestal opening (processed image)

(3) Test results of injecting nitrogen gas into the S/C of Unit-2

The S/C pressure was confirmed to be 3 kPag (as of May 14th, 2013) in a nitrogen gas injecting test into the S/C done in May 2013. The absolute water level in the S/C was not accurately known, but it was confirmed to be approximately on the level of the nitrogen gas inlet (O.P. 3780), because some reasonable pressure due to the water head should exist at the inlet if the S/C were almost filled with water. If the low water level in the

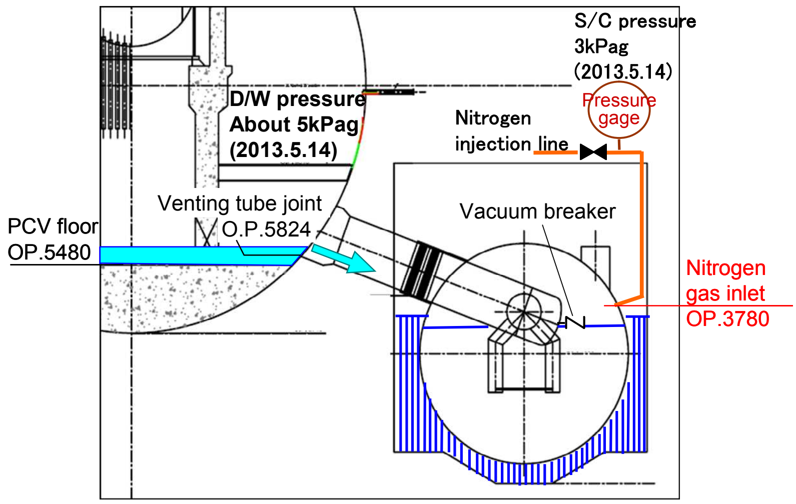


Figure 3-4 Closed space assumed in Unit-2 S/C

D/W is considered in combination, the water injected into the reactor vessel is considered to have reached the S/C via the D/W and venting tubes. If this hypothesis is correct, the current S/C water level will be on the same level as that of water retained in the torus room [14] (Figure 3-4).

Since December 2011, the hydrogen gas concentration and Kr-85 radioactivity measured by the containment gas control system of Unit-2 increased as a consequence of D/W pressure decreasing operations. This test was conducted to check if hydrogen and Kr-85 remained that had originated in the early phase of the accident as in the Unit-1 S/C.

The gradual pressure increase of the S/C from 3kPag to 7kPag before and after the injection confirmed that nitrogen gas had been injected into the S/C. But no change was observed in the hydrogen gas concentration and Kr-85 radioactivity measured by the PCV gas control system. Further tests were conducted to check if this was because there was no flow path from the S/C to the D/W or the hydrogen gas concentration in the S/C was already too low to send response signals.

In July 2013, upon injecting nitrogen gas into the D/W, a D/W pressure increase and an accordingly slight increase of S/C pressure were confirmed. Also in October 2013, upon injecting nitrogen gas into the S/C, the S/C pressure increased to the level of the D/W pressure, after that, both pressures showed similar increasing trends in conjunction. When the nitrogen gas injection to S/C was terminated, the S/C pressure decreased concomitantly with the D/W pressure [15].

From these findings, it was confirmed that nitrogen gas injected into the S/C was flowing to the D/W. And also from findings of nitrogen gas injection into the S/C flowing to the D/W with no change in hydrogen gas concentrations observed in the PCV gas control system, it was concluded that no more hydrogen gas remained in the S/C. It is considered, in this situation, that the vacuum breaker valve (OP. 3305) was not flooded and the nitrogen gas was flowing through this valve, because the water level in the reactor building was below about OP. 3400 during the tests and the S/C water level would follow the torus room water level (torus room water level minus level decrease due to internal pressure)

(4) Investigation of the torus room of Unit-2

In the Unit-2 torus room investigation in April 2012, a robot accessed the gallery inside. Videotaping, dose rates measurement, acoustic checks, etc. were carried out to the extent possible [16].

No water leaking position in the S/C has been located yet. At least, no leak was confirmed on the flange, etc. of the S/C manholes, as far as the camera photos show (Figure 3-5).

---

[14] Handout document, Progress in preparations for decommissioning of Units 1 to 4 of the Fukushima Daiichi Nuclear Power Station, 3rd Decommissioning Measures Steering Panel, May 30, 2013

[15] Handout document, Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 1st Steering Committee towards Decommissioning, December 26, 2013

[16] Handout document, 5th Steering Committee, Government – TEPCO Joint Board on Mid- and Long-term Response Policy, April 23, 2012

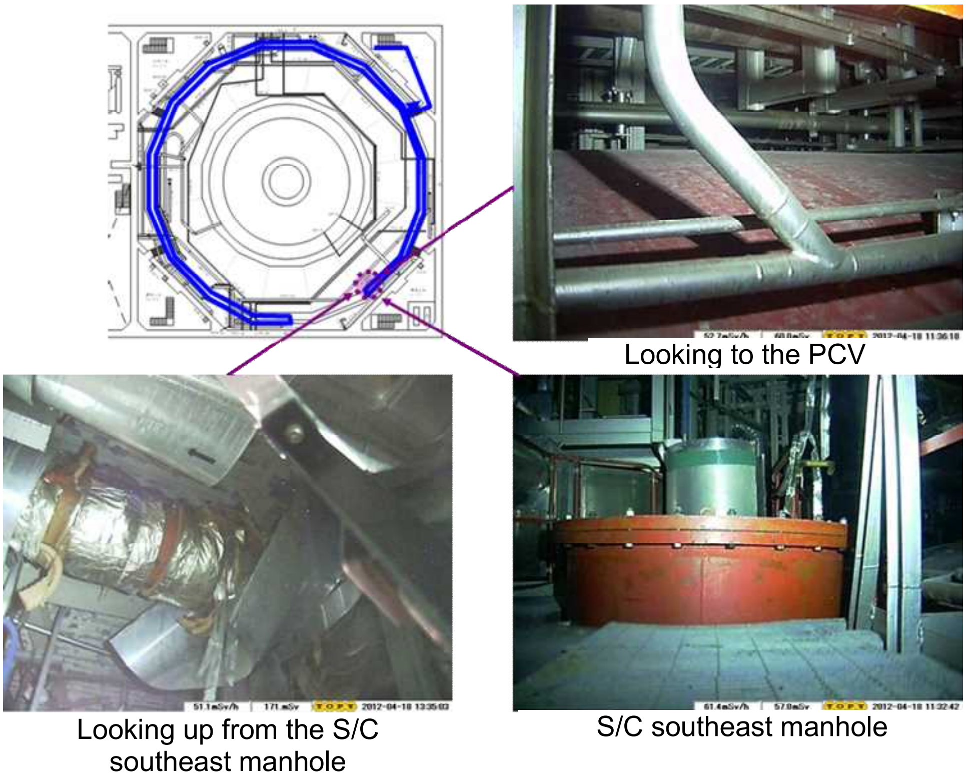


Figure 3-5 Camera photos in the torus room of Unit-2 (part)

(5) Investigation of the situation at the bottom of the vent tubes in the torus room of Unit-2

In the Unit-2 torus room, further investigations were made in December 2012 and March 2013, and the area around the lower end of venting tubes was surveyed by a robot. A small patrol vehicle, which was mounted on the tip of an arm of a four-leg robot, was set on the S/C, from which it accessed the lower end of the venting tube and took photos [17].

No water leaking position in the S/C has been located yet. At least, no leak was confirmed from the lower end of venting tubes within the visible range (Figure 3-6).

[17] Handout document, Progress in preparations for decommissioning of Units 1 to 4 of the Fukushima Daiichi Nuclear Power Station, 1st Decommissioning Measures Steering Panel, March 28, 2013

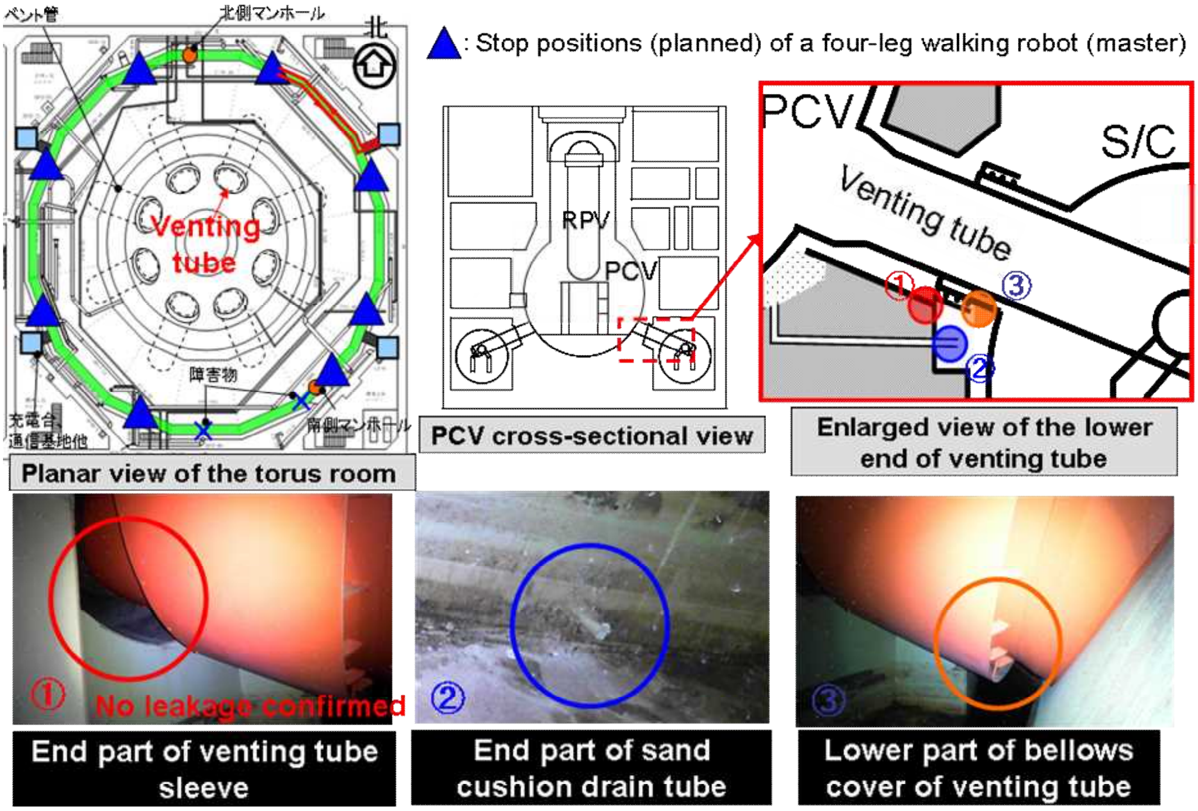


Figure 3-6 Camera photos around the lower end of the venting tubes in the torus room of Unit-2 (part)

(6) S/C water level measurements of Unit-2

In January 2014, the S/C water level was remotely measured using ultrasonic techniques from the chamber outer surface. That is, the ultrasonic waves reflected by the S/C internal structures (as well as the opposite wall) were continuously measured. The water level could be estimated by observing where the reflective waves disappeared (Figure 3-7) [18].

The S/C water level is in correspondence with the level of water retained in the torus room. This is consistent with the water level estimated earlier by the nitrogen gas injection tests. This information confirms that water leaks occurred at the S/C lower position (including piping).

[18] Handout document: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 2nd Decommissioning and Contaminated Water Response Team Joint Meeting, January 30, 2014.

Measurement date	Jan. 14, 2014	Jan.15, 2014	Jan. 16, 2014
S/C water level	About OP. 3210	About OP. 3160	About OP. 3150
Water level retained in the torus room (reference info.)	About OP. 3230	About OP. 3190	About OP. 3160
Level difference	About 20mm	About 30mm	About 10mm
Method of measurement	Direct distance measurement between underwater structures		

(Note) S/C water level seems to be affected by water level retained in the torus room

Measurement scene

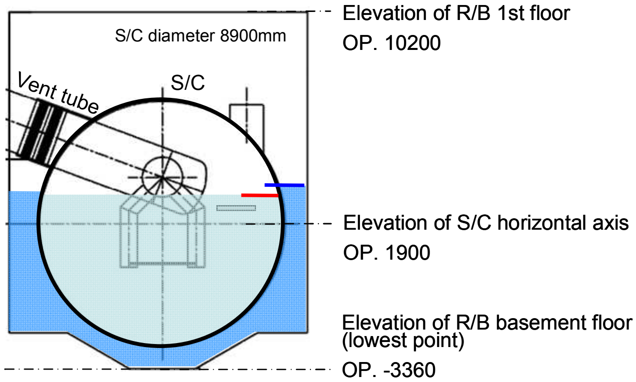
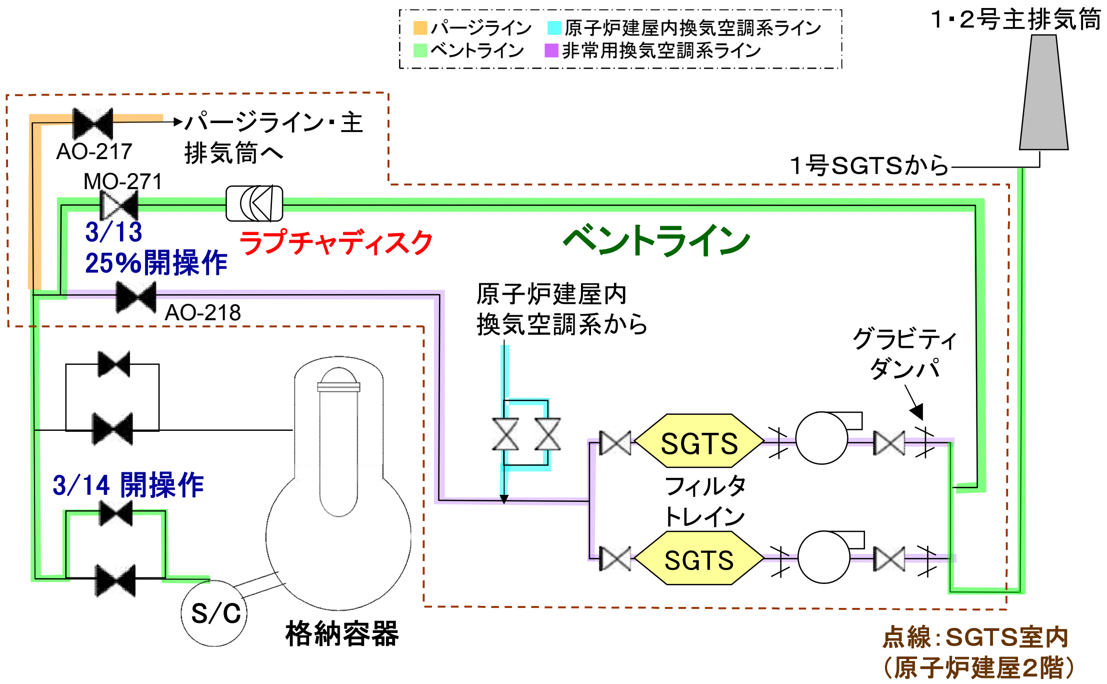


Figure 3-7 S/C water level measurements of Unit-2

(7) Investigations relevant to the rupture disk in the Unit-2 SGTS room

Radiation levels were measured in November 2014, around the rupture disk and the Standby Gas Treatment System (SGTS) filters mounted in the Unit-2 SGTS room as a step to solve the Unit-2/Issue 9 “Rupture disc actuated at Unit-2?“.

Figure 3-8 illustrates the system configuration for venting from the primary containment vessel (PCV) to the Unit-1&2 stack. The green line is the venting line to release the PCV pressure when it exceeds its design pressure. This venting line bypasses the SGTS filters mounted, as early as the very beginning of the construction phase, on the emergency heating and ventilation air conditioning system. This venting line is also connected to the purge line as well as the reactor building heating and ventilation air conditioning (RB HVAC) system line. Valves in the figure are shown in black when fully closed, or when the opening aperture is unknown, and white when fully opened. The opening aperture of the valve (MO-271) located immediately upstream from the rupture disk was recorded as being operated to 25% mid-open position as of March 13th, 2011. The valve continues to hold the state even now. On the other hand, the valve immediately downstream on the S/C side of the PCV was operated to open its large and small vent valves until March 14th, 2011, but their real states when the venting line pressure reached the rupture disk working pressure remain unknown.

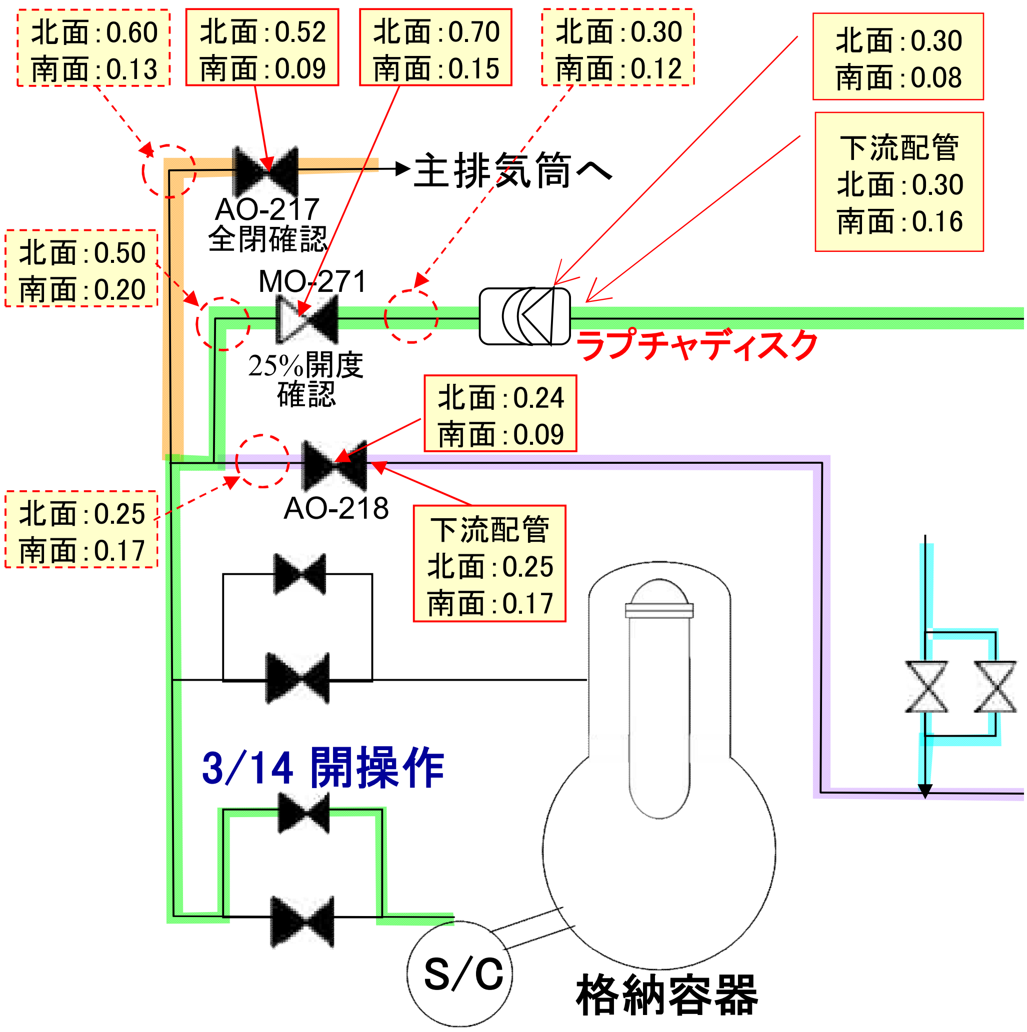


パージライン	Purge line
原子炉建屋内換気空調系ライン	RB HVAC line
ベントライン	Venting line
非常用換気空調系ライン	Emergency HVAC line
１・２号排気等	Unit-1&2 stack
１号 SGTS から	From Unit-1 SGTS
3/13 25% 開操作	25% opening operation on March 13th
ラプチャディスク	Rupture disc
フィルタートレイン	Filter train
グラビティーダンパ	Gravity damper
格納容器	PCV
点線：SGTS 室内（原子炉建屋２階）	Dotted line: In SGTS room (RB 2nd floor)

Figure 3-8 System configuration relevant to the rupture disk

Figure 3-9 shows the results of radiation measurement around the rupture disk. The measurement was done on October 8th, 2014. The radiation level measured was 0.30mSv/h from the north face, while it was 0.08mSv/h from the south face. Both were at about the same level of 0.30mSv/h (north face) and 0.12mSv/h (south face) before the rupture disk on the venting line, or 0.30mSv/h (north face) and 0.16mSv/h (south face) after the disk. These values indicate that the area is not contaminated to the extent predictable for such lines as the Unit-1 venting line, through which gas containing a large amount of radioactive materials went.

Furthermore, there exists a consistent tendency in the surrounding area that the levels on the north face are higher than those on the south face. This may indicate that the observed radiation levels were influenced by some unknown high level radioactive source existing on the north side of the rupture disk area, i.e., the radiation levels observed on the north face of the venting line and the rupture disk were actually measurements of radiation coming from that unknown high level radioactive source on the north side without the shielding effect of the piping, while the radiation levels obtained on the south face were actually measured after being shielded by the piping. Therefore, it is highly likely that the rupture disk and the piping around the disk are the least contaminated.



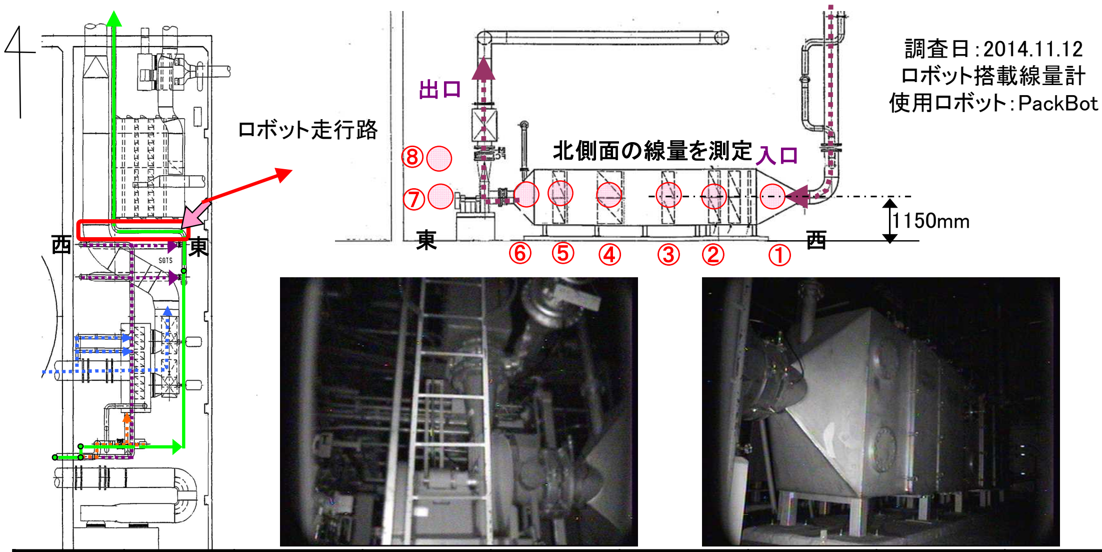
北面	North face
南面	South face
主排気筒	Stack
全閉確認	Full-closure confirmed
25%開度確認	25% aperture confirmed
下流配管	Line after (the rupture disk)
開操作	Opening operation
格納容器	PCV

Figure 3-9 Radiation levels observed around the rupture disk (mSv/h)

As described above, the unknown high level radioactive source on the north side of the rupture disk area was assumed to be fairly strong. For this reason, the radiation measurement on the north side was conducted using a robot (November 12th, 2014).

Figures 3-10 and 3-11 show the radiation measurement results around the SGTS filters (A) and (B), respectively. For both filters (A) and (B), radiation levels as high as about 1Sv/h were obtained. The maximum contamination has been observed on the HEPA filter at the SGTS filter outlet. Generally, the SGTS filter captures radioactive materials from its inlet side, which means that the results observed may indicate the gas containing the radioactive materials flowed into the SGTS filter from the opposite direction (backward flow). As clearly recognizable from Figure 3-8, there are two possible paths for this backward flow: from the Unit-2 venting line and the Unit-1 venting line (this is the same situation as having occurred when hydrogen gas flowed backward from Unit-3 to Unit-4).

Contamination around the rupture disk was not confirmed by the radiation measurements in the relevant area in October 2014. But still the information is insufficient in order to judge whether the Unit-2 rupture disk worked at the accident. Therefore, the investigation continues on this issue, including the identification of the source which contaminated the SGTS filters.



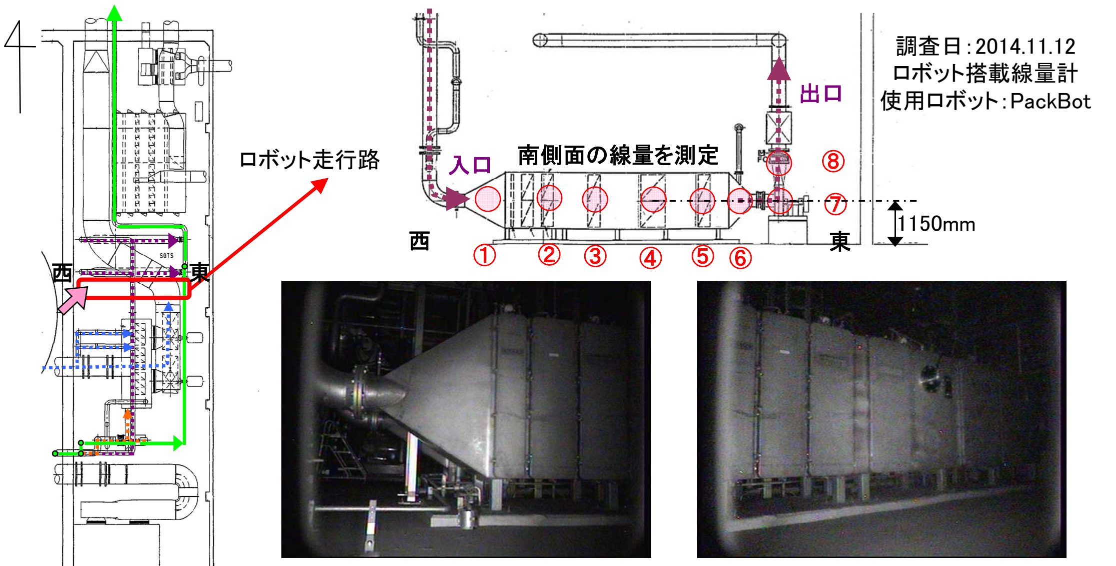
測定場所	⑧-A	⑦-A	⑥-A	⑤-A	④-A	③-A	②-A	①-A
	出口配管	出口配管	出口部	HEPAフィルタ	チャコールフィルタ	HEPAフィルタ	プレフィルタ	入口部
測定高さ	2170mm	1150mm	1150mm	1150mm	1150mm	1150mm	1150mm	1150mm
線量率	79mSv/h	85mSv/h	400mSv/h	1Sv/h *	460mSv/h	220mSv/h	140mSv/h	69mSv/h

*) フィルタトレイン表面から約20cm離れた位置（フィルタ中心面より約65cm）で測定した線量値

*) Measured at the point about 20cm from the filter train surface (about 65cm from the filter center)

ロボット走行路	Robot guide way
北側面の線量を測定	Dose measured on the north face
ロボット搭載線量計	Dosimeter mounted on a robot
使用ロボット	Robot used
測定場所	Point of measurement
測定高さ	Elevation of measurement
線量率	Dose rate
出口配管	Outlet pipe
出口部	Outlet
HEPA フィルター	HEPA filter
チャコールフィルター	Charcoal filter
プレフィルター	Prefilter
入口部	Inlet

Figure 3-10　Radiation level observed (SGTS filter (A))



測定場所	①-B 入口部	②-B プレフィルタ	③-B HEPAフィルタ	④-B チャコールフィルタ	⑤-B HEPAフィルタ	⑥-B 出口部	⑦-B 出口配管	⑧-B 出口配管
測定高さ	1150mm	1150mm	1150mm	1150mm	1150mm	1150mm	1150mm	2170mm
線量率	15mSv/h	29mSv/h	44mSv/h	160mSv/h	850mSv/h＊	500mSv/h	210mSv/h	120mSv/h

＊) フィルタトレイン表面から約20cm離れた位置（フィルタ中心面より約65cm）で測定した線量値

*) Measured at the point about 20cm from the filter train surface (about 65cm from the filter center)

南側面の線量を測定	Dose measured on the south face

Figure 3-11 Radiation level observed (SGTS filter (B))

(8) Investigation of the area around PCV penetration X-6

In preparation for the internal investigation of the PCV and pedestal, shield blocks and iron plates were removed (between June 11th to October 1st, 2015) from the front of PCV penetration X-6 (see Figure 3-12 Building layout), which had been selected as the access route. When the area around the penetration was investigated, during the removal work, some melted material was found and a high radiation dose of more than 1,000mSv/h was noticed on the penetration flange and on the floor.

Figure 3-13 shows a photo of the melted material. The melt hung from the penetration flange and lay spread on the floor. It is thought to be materials that had covered cables of the CRD replacement machine or O-ring materials of the penetration flange seals. The melt on the floor was solidified and confirmed to be easily removable by spatulas or similar tools.

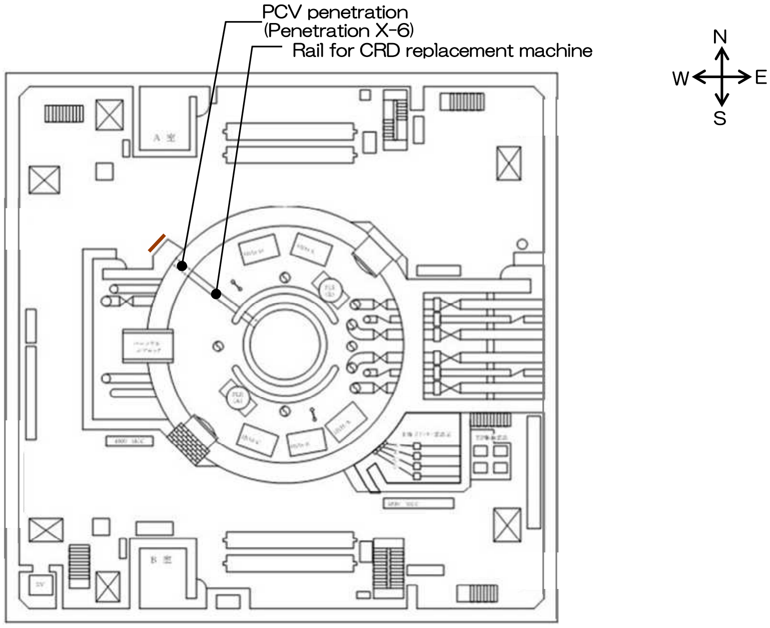


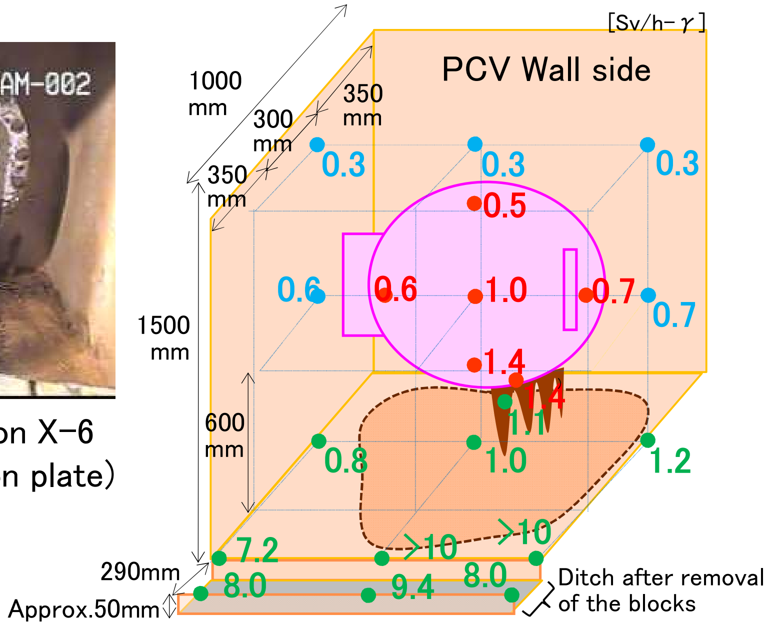
Figure 3-12 Layout on the ground floor of Unit-2 R/B [19]

Figure 3-13 Melted material at the penetration flange [20]

[19] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 19th Decommissioning and Contaminated Water Response Team Joint Meeting, June 25, 2015
[20] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 21st Decommissioning and Contaminated Water Response Team Joint Meeting, August 27, 2015

Figure 3-14 gives the radiation dose rate measured on the surface. An increasing tendency for the surface dose is noticed in the order: “on the ceiling < in the middle < on the floor”; and especially a high dose rate is observed in the ditch after the shield blocks had been removed. The contamination might have spread from the area where the melt lay to the ditch. If the radiation dose difference between the locations of “at the penetration” and “on the wall” comes from the contribution of a radiation source inside the penetration X-6, it is estimated to be approximately 1Sv/h at the maximum.

Flange of Penetration X-6
(after removal the iron plate)



Red: Surface dose rate on the penetration surface
Blue: Surface dose rate on the ceiling/wall
Green: Surface dose rate on the floor and the molten object

Figure 3-14 Measurement results of surface radiation dose rate [21]

[21] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 23-rd Decommissioning and Contaminated Water Response Team Joint Meeting, October 29, 2015

4. Conditions of Unit-3 core and PCV

(1) Investigation of torus room

In the Unit-3 torus room investigation in July 2012, a robot accessed the gallery inside. Videotaping, dose rates measurement, acoustic checks, etc. were also carried out to the extent possible [22].

No water leaking position in the S/C was located yet. At least, no leak was confirmed on the flange, etc. of the S/C manholes, as far as the camera photos show (Figure 4-1).

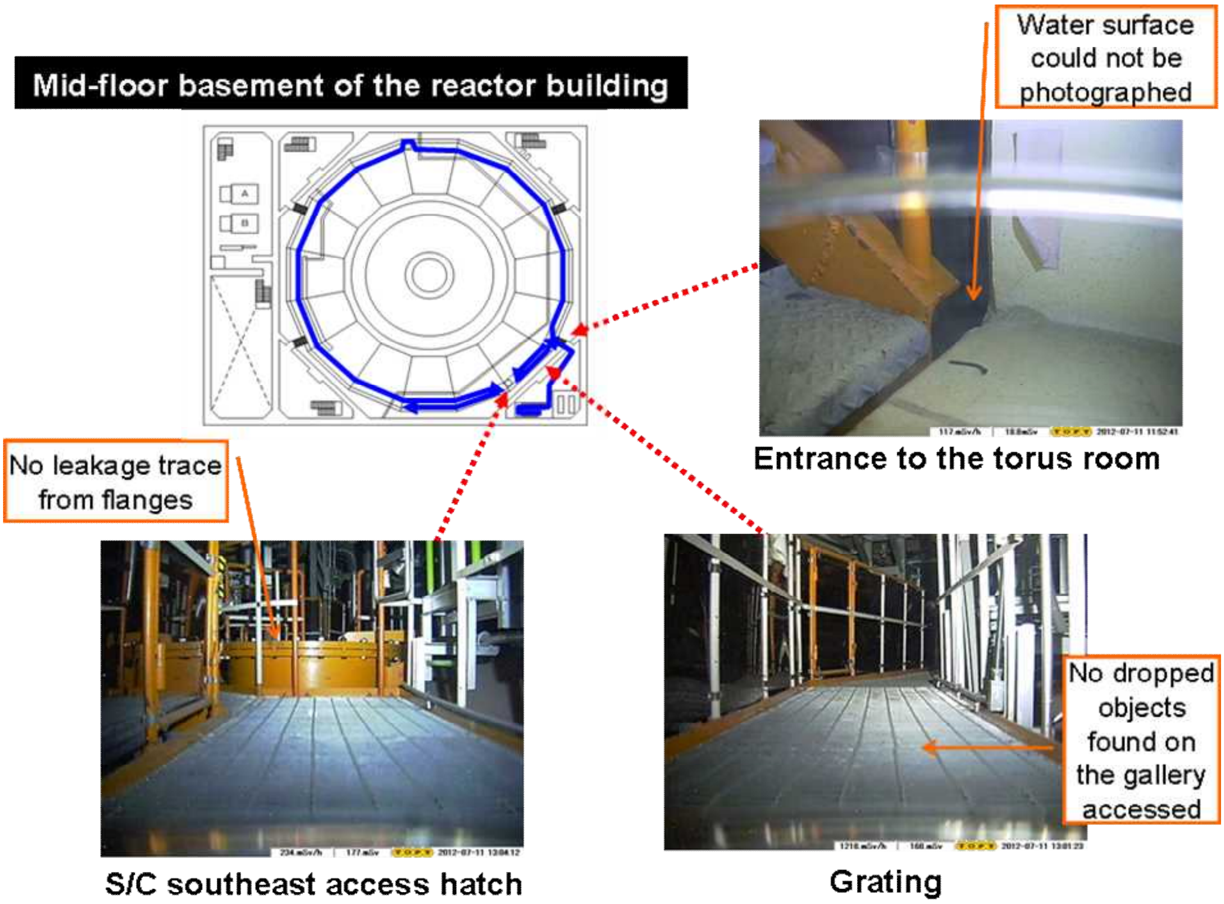


Figure 4-1 Camera photos in the torus room of Unit-3 (part)

(2) Oxygen concentrations in the PCV

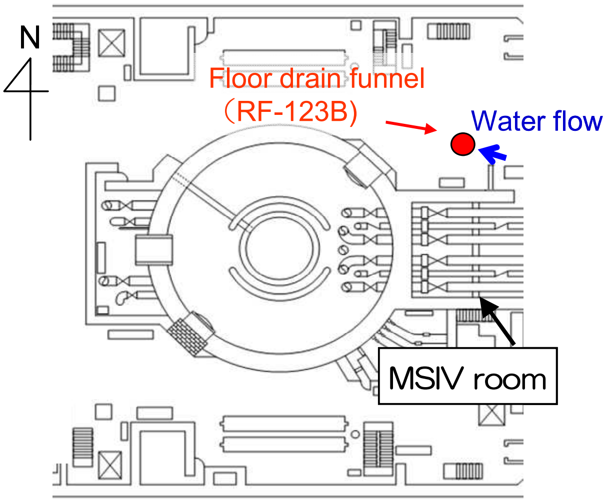
Nitrogen is being sent to the PCV in order to maintain an inert atmosphere, while the containment gas control system discharges the same amount of gas from the PCV. It was confirmed through analyzing the discharged gas that the oxygen concentrations in the PCVs of Unit-1 and Unit-2 were nearly zero, while that in Unit-3 was about 8% (July 2012 [23]), analyzed again in March and April of 2013). Containment pressures of Unit-1 and Unit-2 PCVs are at

[22]Handout document, 8th Steering Committee, Government – TEPCO Joint Board on Mid- and Long-term Response Policy, July 30, 2012
[23] "Conditions in the containment vessels based on the measurements of the atmospheric gases", Technical Workshop for the Accident of the Fukushima Daiichi Nuclear Power Plant, July 23, 2012

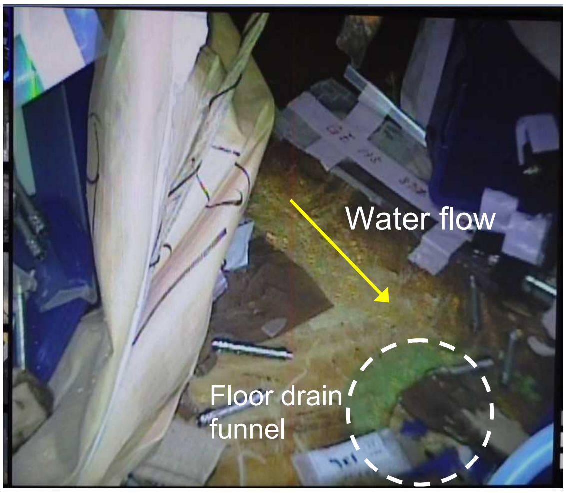
several kPa, and remaining positive, while the pressure of the Unit-3 PCV is almost constantly at the level of the atmospheric pressure. Consequently, the gas leak rate of the Unit-3 PCV was confirmed to be the highest.

(3) Survey results of leaked water in the MSIV room of Unit 3

In January 2014, while camera photos taken by the rubble and wreckage removal robot in the Unit 3 reactor building were being checked, water was seen to be flowing from near the main steam isolation valve (MSIV) room door in the northeast area of the reactor building first floor. The water was flowing towards a nearby floor drain funnel (Figure 4-2) [24].



Simplified plan view of Unit 3 R/B 1st floor



(Photo on Jan. 18, 2014)

Figure 4-2 Water leak near the MSIV room door of Unit-3

The water level in the PCV is estimated as about OP.12m (about 2 m above the reactor building first floor) by converting the S/C pressure obtained by the existing pressure indicators to water head. This elevation is on the level of PCV penetrations for main steam lines, thus indicating the possibility of water leaks from the PCV penetration in the MSIV room as the source of the water flow. In consideration of this possibility, instrumentation was inserted into the MSIV room from the HVAC system room on the floor above, in April and May 2014, and photos were taken and dose rates were measured in the room, in order to locate the water flows in the room. Water leaks were from near the expansion joint of main steam line D. It was concluded [25] that the leakage had occurred only from the main steam line D, based on: (1) confirmation of no leaks from the main steam lines A, B and C, and their main steam drain pipes; and (2) the flow directions of leaked water on the floor.

[24] Handout document, Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 2nd Decommissioning and Contaminated Water Response Team Joint Meeting, January 30, 2014.
[25] Handout document, Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 6th Decommissioning and Contaminated Water Response Team Joint Meeting, May 29, 2014.

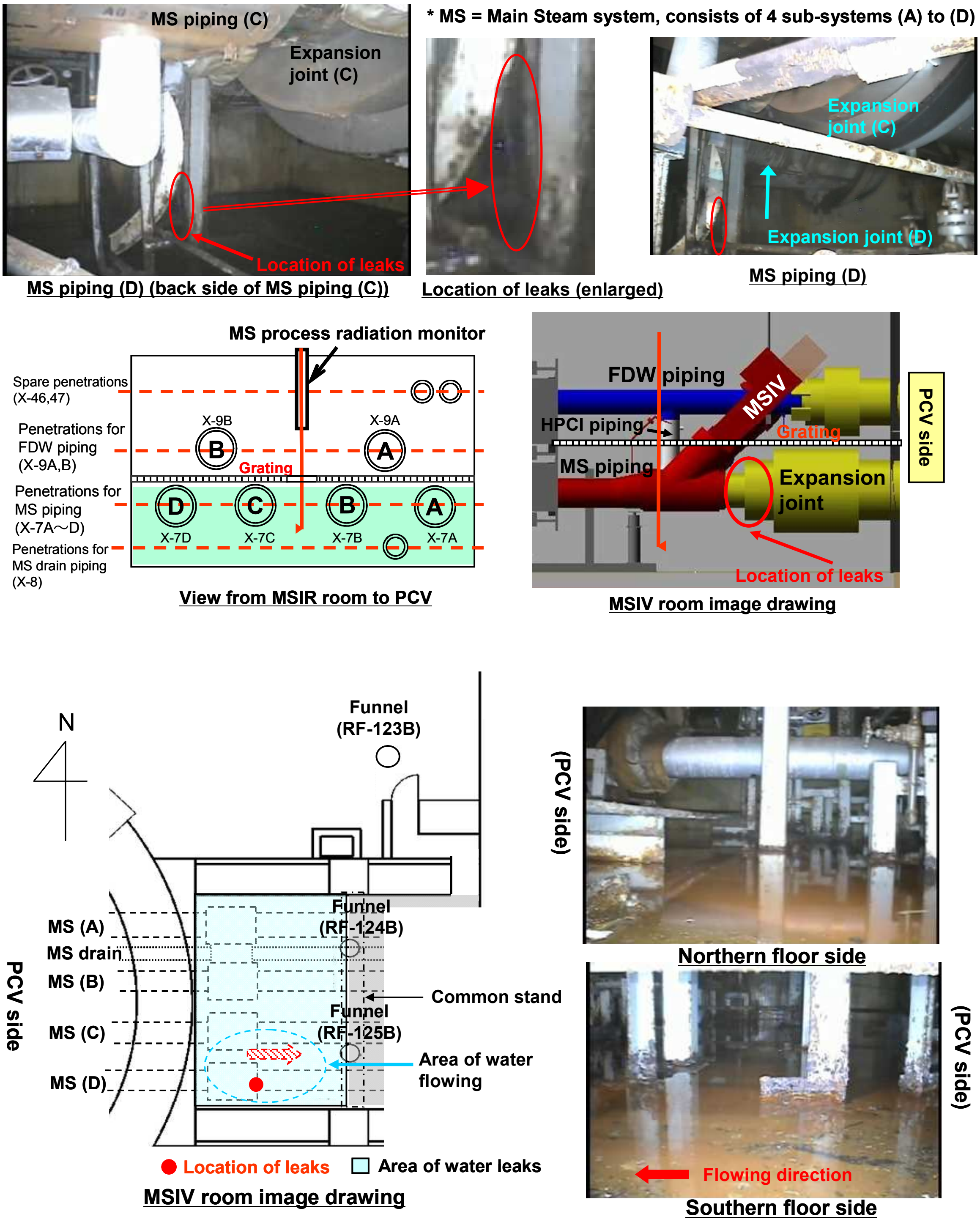


Figure 4-3　Water leaks from main steam line D in MSIV room

(4) Investigation of PCV equipment hatch of Unit-3

In order to locate the leak path from the PCV, the PCV equipment hatch on the R/B ground floor was investigated on September 9th, 2015. In this area of the equipment hatch, it has been known from the earlier investigation (in 2011) that the shield plug, which was to be located in front of the equipment hatch during normal operation and be replaced forward for maintenance during outage, was unexpectedly moved onto the rails and high dose rate water was confirmed to have been left in the ditches for the shield plug rails and in their vicinities. A possibility was pointed out therefore that the water retained in the PCV had leaked out through the equipment hatch seals.

In the current investigation, a small camera was inserted through the space between the shield plug and the wall originally surrounding the shield plug and the equipment hatch conditions were surveyed. Figure 4-4 presents photos taken of the hatch and around it. No water leaks from the hatch were recognized and no deformation of the hatch itself was recognized, either. Furthermore, no damage was found on the materials for periodic inspections that had been stored in front of the equipment hatch. Rather, it was noticed that the surface coating on the equipment hatch had come off and fragments of coating and other things had been accumulated on the floor in front of the equipment hatch.

At the original location for the shield plug, water (raindrops or condensed dew) was dripping from above and the floor seemed wet. Water puddles were recognized in the ditches for the shield plug travelling rails.

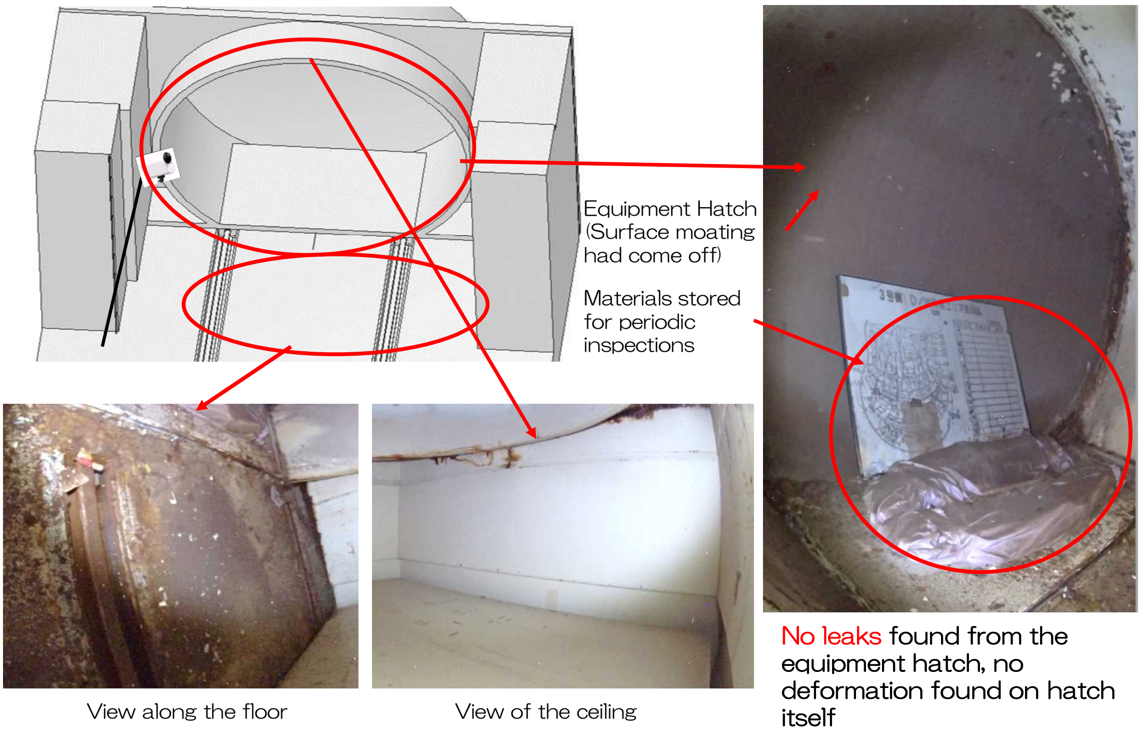


Figure 4-4 Photos of the equipment hatch [26]

(5) Investigation inside the PCV of Unit-3

The interior of the PCV of Unit-3 was investigated on October 20th and 22nd by inserting an investigation probe through penetration X-53 for taking photos, checking water levels and measuring temperatures and dose rates. The retained water was sampled for water quality analysis.

Figure 4-5 shows photos of the penetration X-53 taken from the front. Structures like piping, a

[26] Handout document: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 22nd Decommissioning and Contaminated Water Response Team Joint Meeting, October 1, 2015

ladder and other things were visible, but no damage was recognized. Including the underwater photos, no damage was recognized in the PCV in the current investigation.

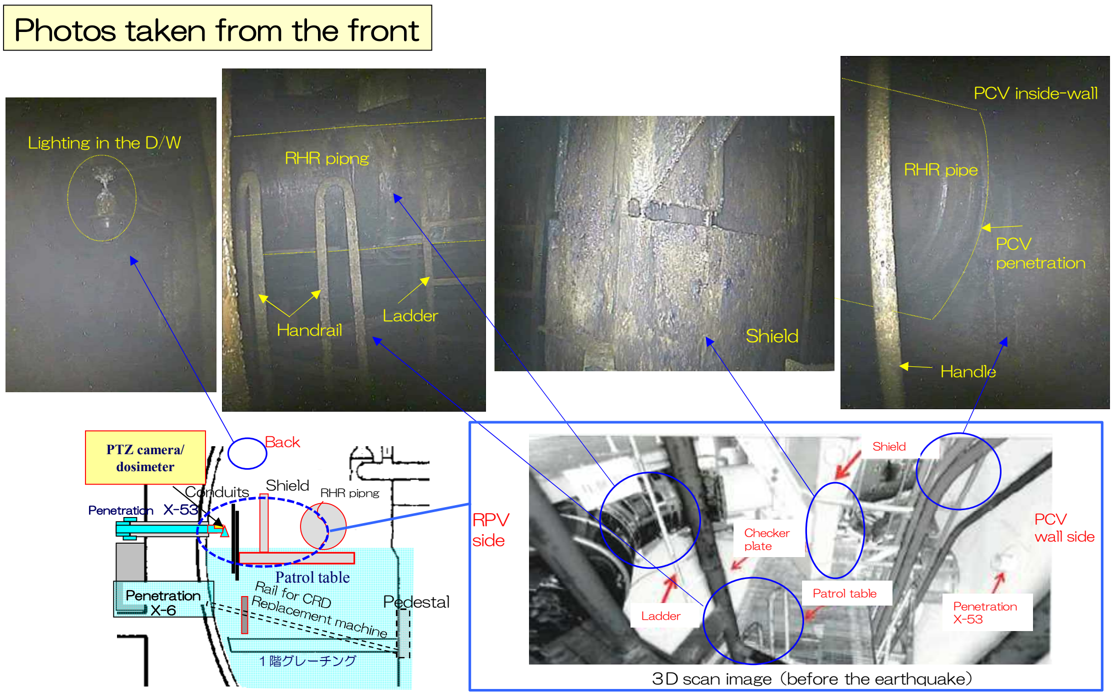


Figure 4-5 Photos of penetration X-53 taken from the front[27]

Figure 4-6 shows photos taken underwater by a PTZ camera. The camera was inserted through penetration X-53. Sediments were recognized on the grating and the rails for the CRD replacement machine.

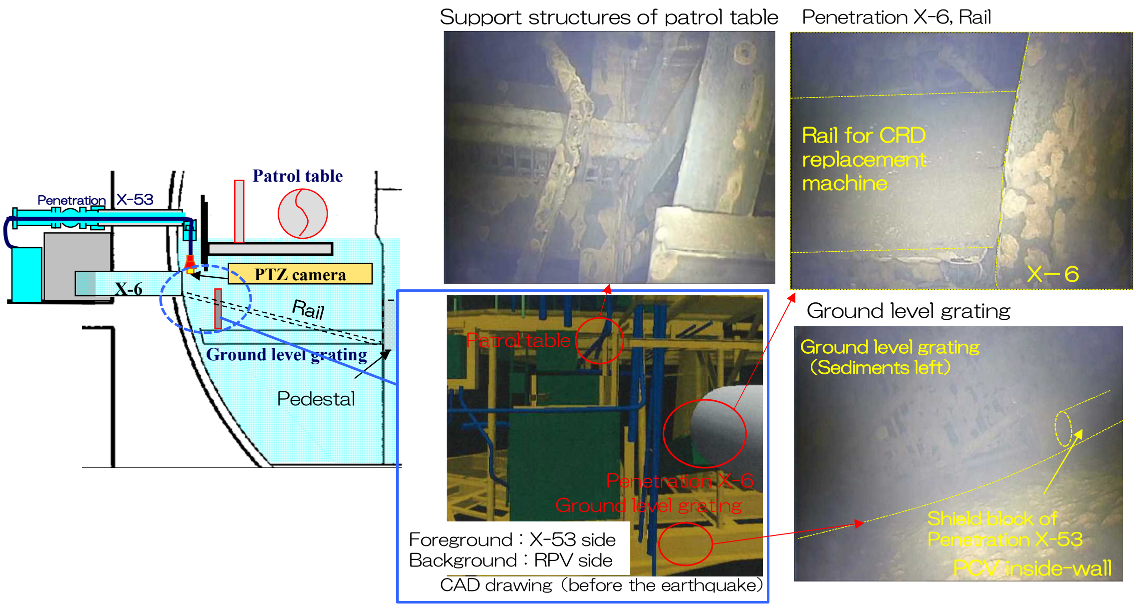


Figure 4-6 Photos in the water retained in the PCV[28]

[27] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 23rd Decommissioning and Contaminated Water Response Team Joint Meeting, October 29, 2015
[28] Handout document 3: Action progress towards decommissioning of Units 1 to 4 of Fukushima Daiichi Nuclear Power Station, 23rd Decommissioning and Contaminated Water Response Team Joint Meeting, October 29, 2015

The level of the water retained in the PCV was about OP11,800 or about 70cm below the penetration X-53. It was roughly in agreement with the value estimated from the PCV pressures. The temperatures in the PCV were about 26 to 27 deg C in the air and about 33 to 35 deg C in the water. The air dose rate measured in the PCV was about 0.75Sv/h at a point about 55cm from the exit of penetration X-53, and 1Sv/h near the PCV inner wall.

The results of quality analysis of retained water that was sampled are given in Table 4-1. Samples were taken at two positions, one about 10cm below the surface and the other about 70cm below it. The results showed that the water was not strongly corrosive. In the water, α-emitting nuclides were detected in addition to cesium and tritium.

Objective	Items of analysis (planned)		Near surface	About 70cm below surface	Evaluation
Corrosiveness of the environment	pH		6.8	6.3	Not strongly corrosive
	Conductivity (μS/cm)		14.0	10.2	
	Chlorine concentration (ppm)		Below detection limit (<1)	Below detection limit (<1)	
Radioactive materials released, nuclide migration behavior	γ-concentration (Bq/cm^3)	^{134}Cs	4.0E02	2.3E+02	
		^{137}Cs	1.6E+03	9.4E+02	
		^{131}I	Below detection limit (<8.1E+00)	Below detection limit (<5.3E+00)	
	Tritium concentration (Bq/cm^3)		2.7E+02	1.6E+02	
	^{89}Sr/^{90}Sr concentration (Bq/cm^3)		^{89}Sr: below detection limit (<8.4E+01) ^{90}Sr: 7.4E+03	^{89}Sr: below detection limit (<8.1E+01) ^{90}Sr: 3.9E+03	
	Total α concentration (Bq/cm^3)		2.1E+00*	9.7E+01*	

Table 4-1 Results of water quality analysis of the water retained in the PCV [28]

(End)