Investigations concerning the estimation of core and in-containment conditions

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 Plant.

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.

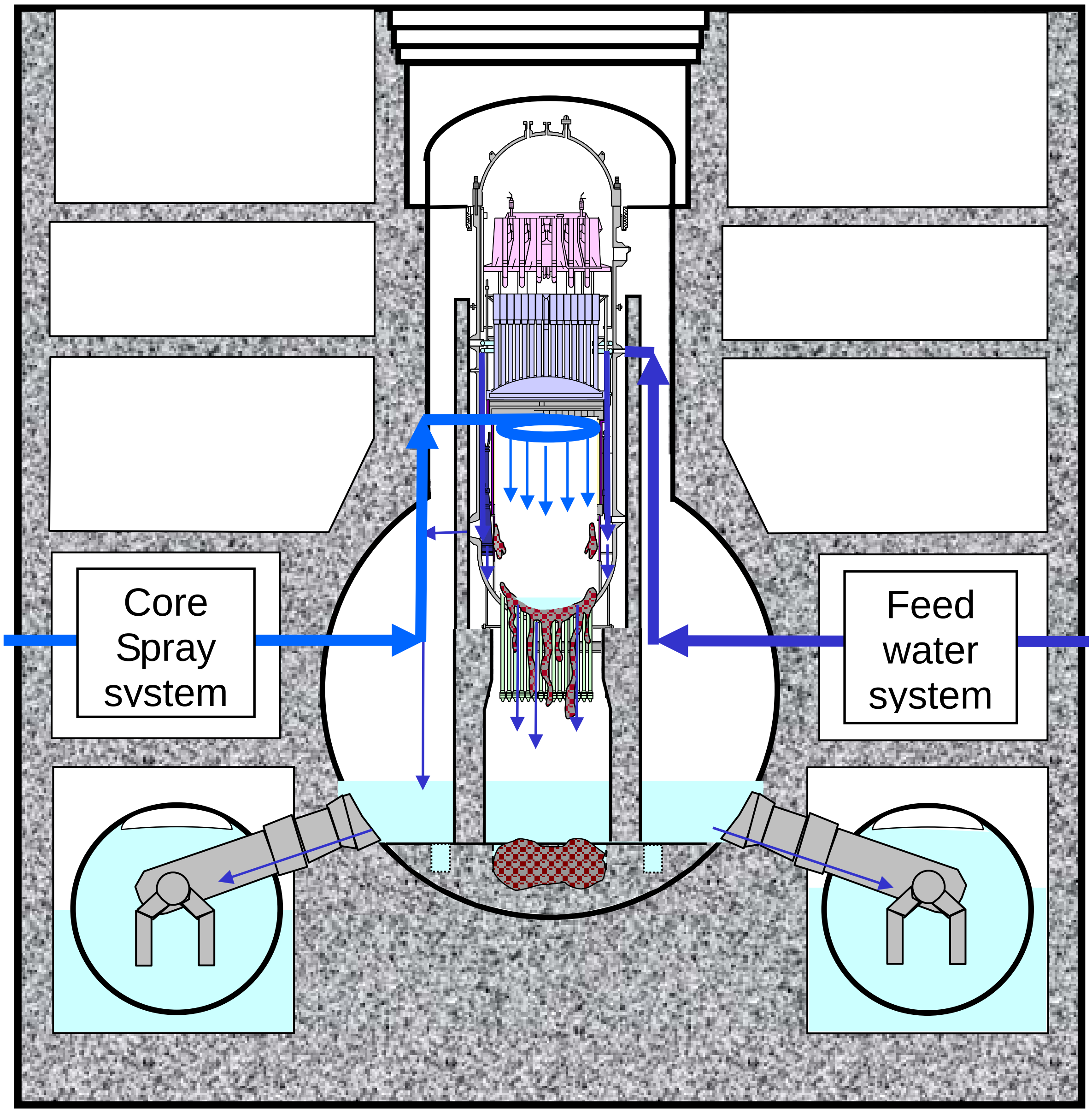

Figure 1-1　Estimated conditions of the core and PCV of Unit-1

(Note) The illustration is not accurately representing a quantitative image for the size, etc. of debris.

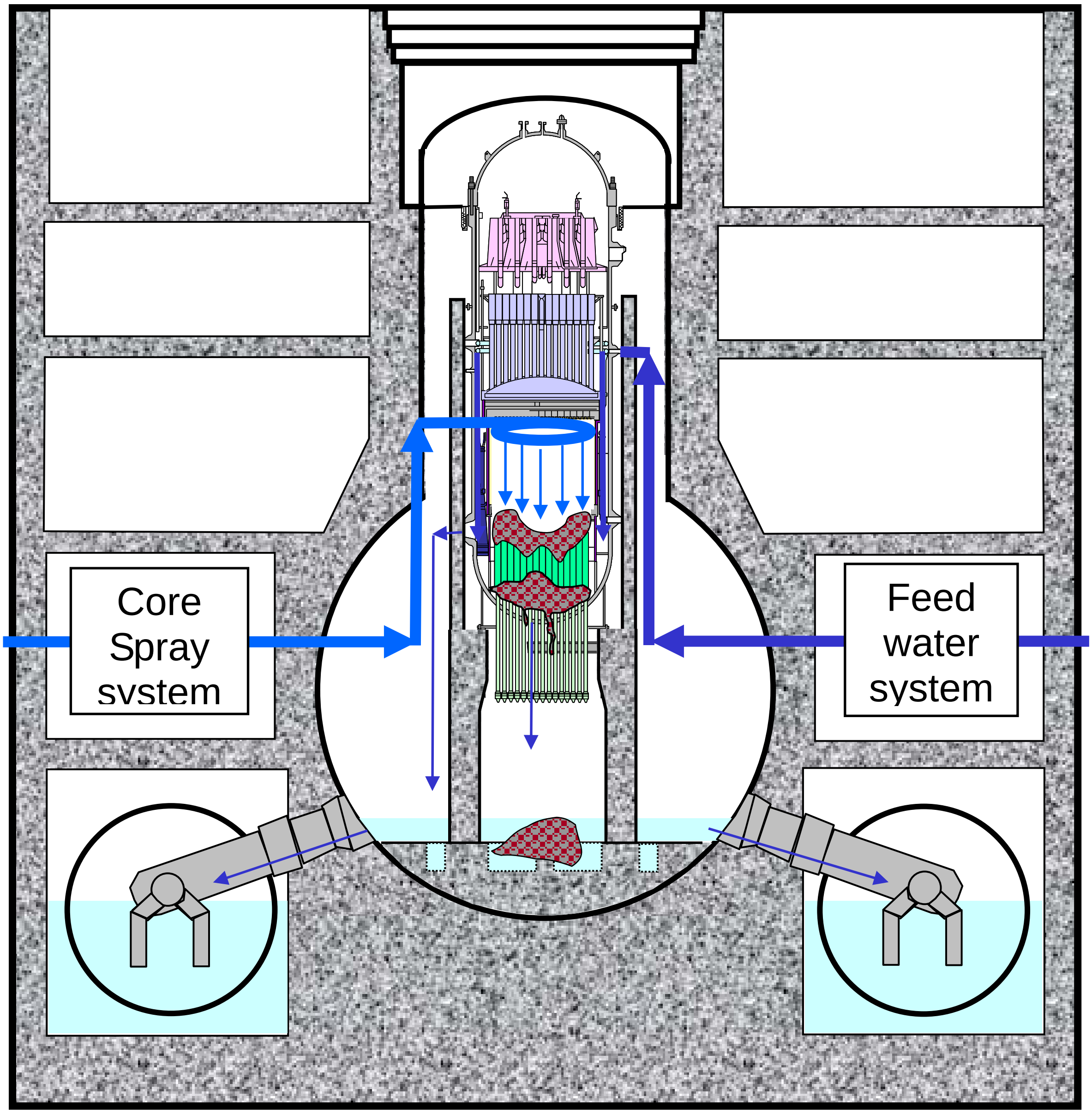

Figure 1-2　Estimated conditions of the core and PCV of Unit-2

(Note) In the earlier figure as of November 30th, 2011, the amount of debris on the PCV pedestal looked small (it was drawn so, because the fractions of fuel that remained in the core region and fell to the bottom or the pedestal of the reactor vessel or PCV had been unknown). The fallen debris on the PCV pedestal was shown as larger this time to avoid the misunderstanding that the reactor vessel had not been ruptured. The illustration is not accurately representing a quantitative image for the size, etc. of debris.

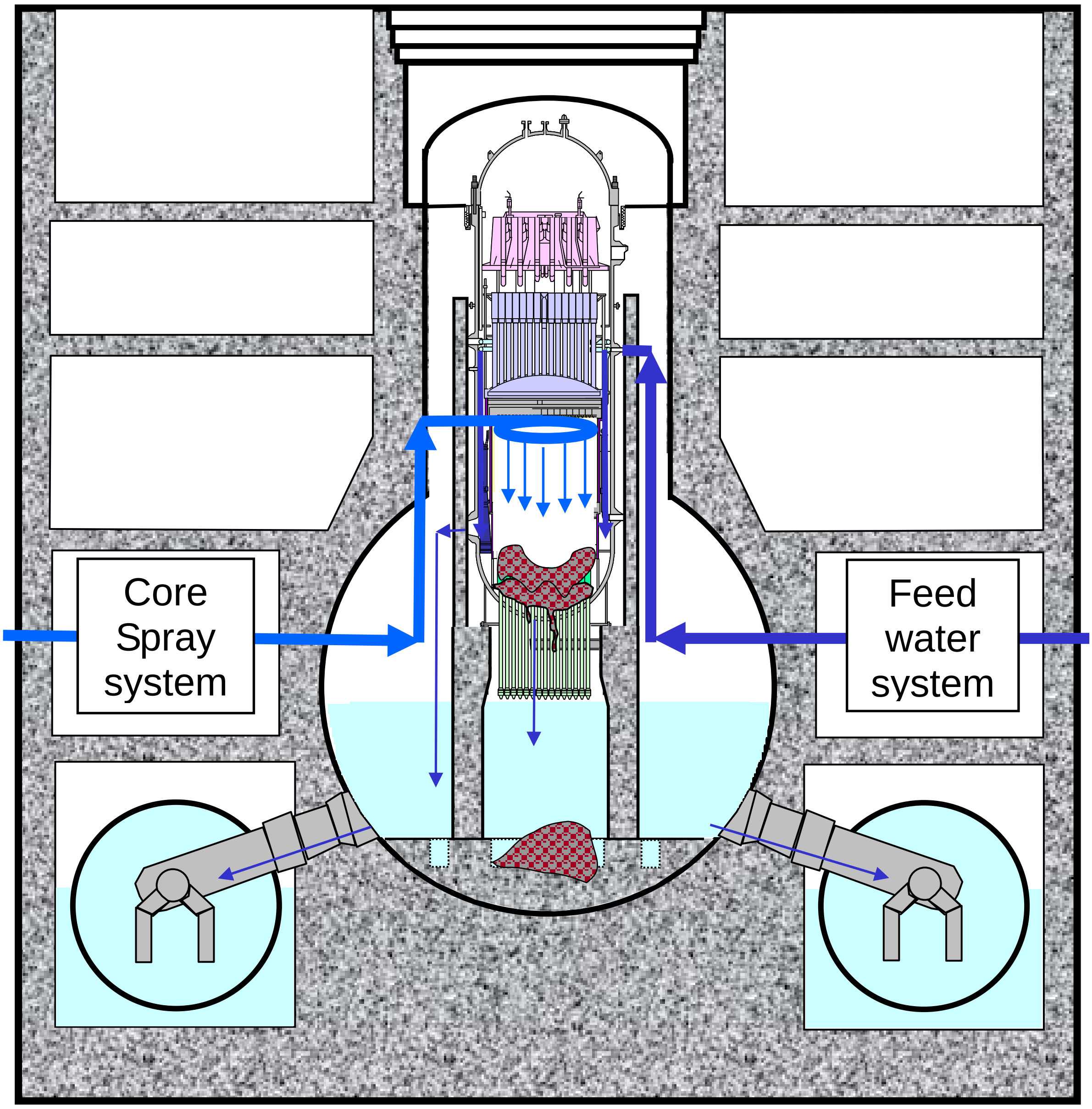

Figure 1-3 Estimated conditions of the core and PCV of Unit-3

(Note) In the earlier figure as of November 30th, 2011, the amount of debris on the PCV pedestal looked small (it was drawn so, because the fractions of fuel that remained in the core region and fell to the bottom or pedestal of the reactor vessel or PCV had been unknown). The fallen debris on the PCV pedestal was shown as larger this time, because it was considered that the accident might have developed faster than predicted before. This was based on the new finding that sufficient water injection to the reactor had become impossible before the operator manually stopped the HPCI. The illustration is not accurately representing 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).

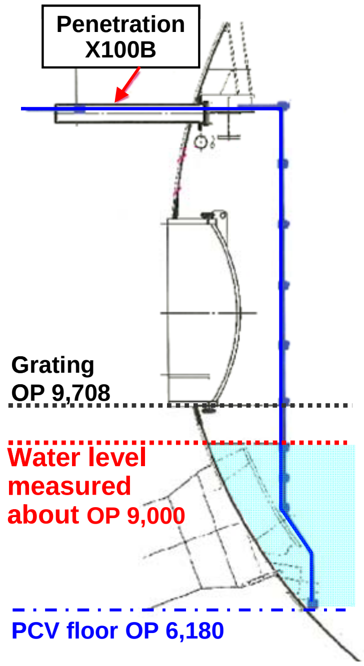

Figure 2-1 Measured level of water retained in Unit-1 PCV

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

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 o fthe 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

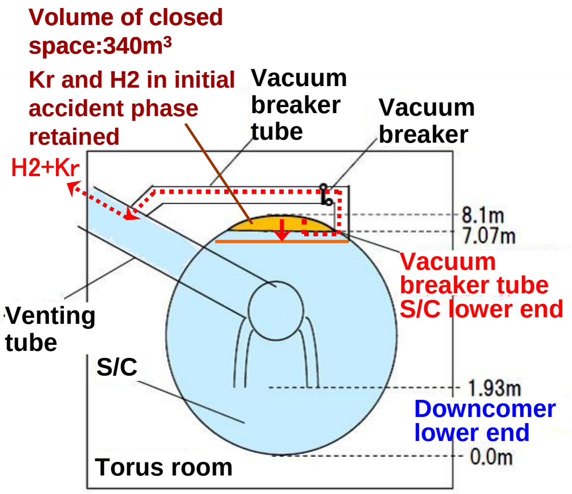

Figure 2-2 Closed space in gaseous phase inside S/C of Unit-1

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

*2) Handout documents, 9th and 10th Steering Committees, Government – TEPCO Joint Board on Mid- and Long-term Response Policy, August 27th and September 24th, 2012 the following sequence: When the S/C water 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

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) .

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).

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

*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 7th, 2013

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*4) 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).

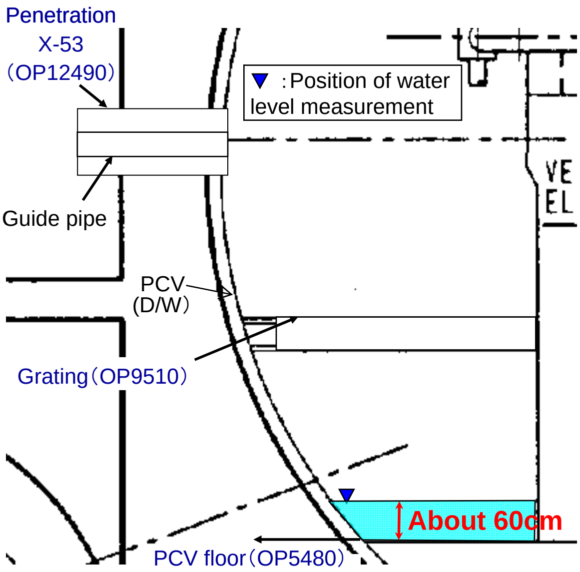


Figure 3-1 Measured level of retained water in Unit-2 PCV

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

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 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*5) (Figure 3-2).

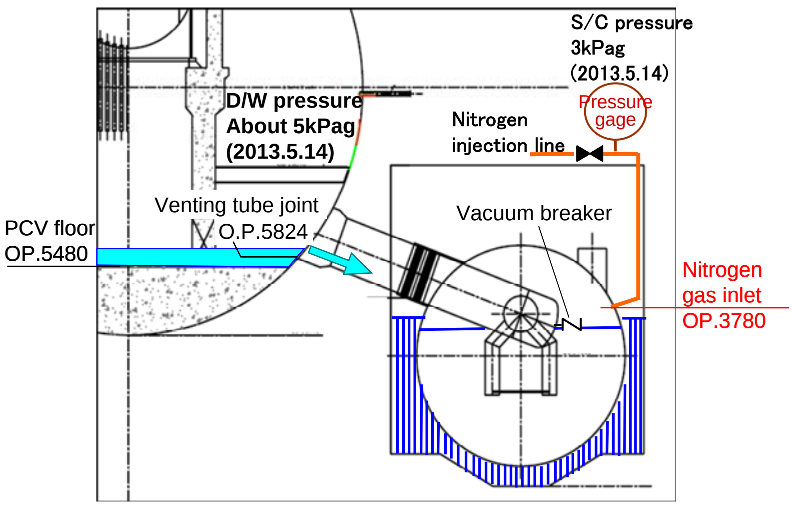


Figure 3-2 Closed space assumed in Unit-2 S/C

Since December 2011, the hydrogen gas concentration and Kr-85 radioactivity measured by the

*4) Results of PCV investigation and plan for identifying leak path, Technical workshop for Fukushima Daiichi accident, July 24th, 2012

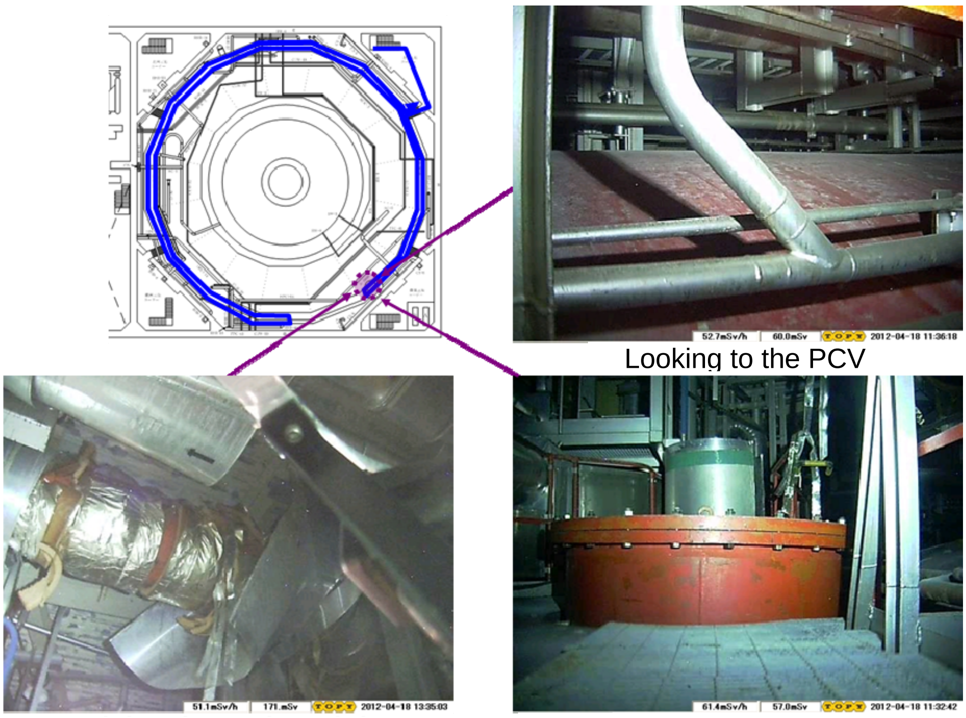
*5) Progress in preparations for decommissioning of Units-1 to 4 of the Fukushima Daiichi Nuclear Power Plant, May 30th, 2013 containment gas control system of Unit-2 increased as a consequence of D/W pressure decreasing operations. This test was conducted to check if hydrogen and Kr-85 remained that 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 containment gas control system. Further tests are underway to check if this is because there is no flow path from the S/C to the D/W or the hydrogen gas concentration in the S/C is already too low to send response signals.

(3) Investigation of the torus room

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*6).

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 3-3).



Looking to the PCV

Looking up from the S/C southeast manhole

S/C southeast manhole

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

In the Unit-2 torus room, further investigations were made in December 2012 and March 2013,

*6) Progress in preparations for decommissioning of Units-1 to 4 of the Fukushima Daiichi Nuclear Power Plant, March 7th, 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*7) .

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 3-4).

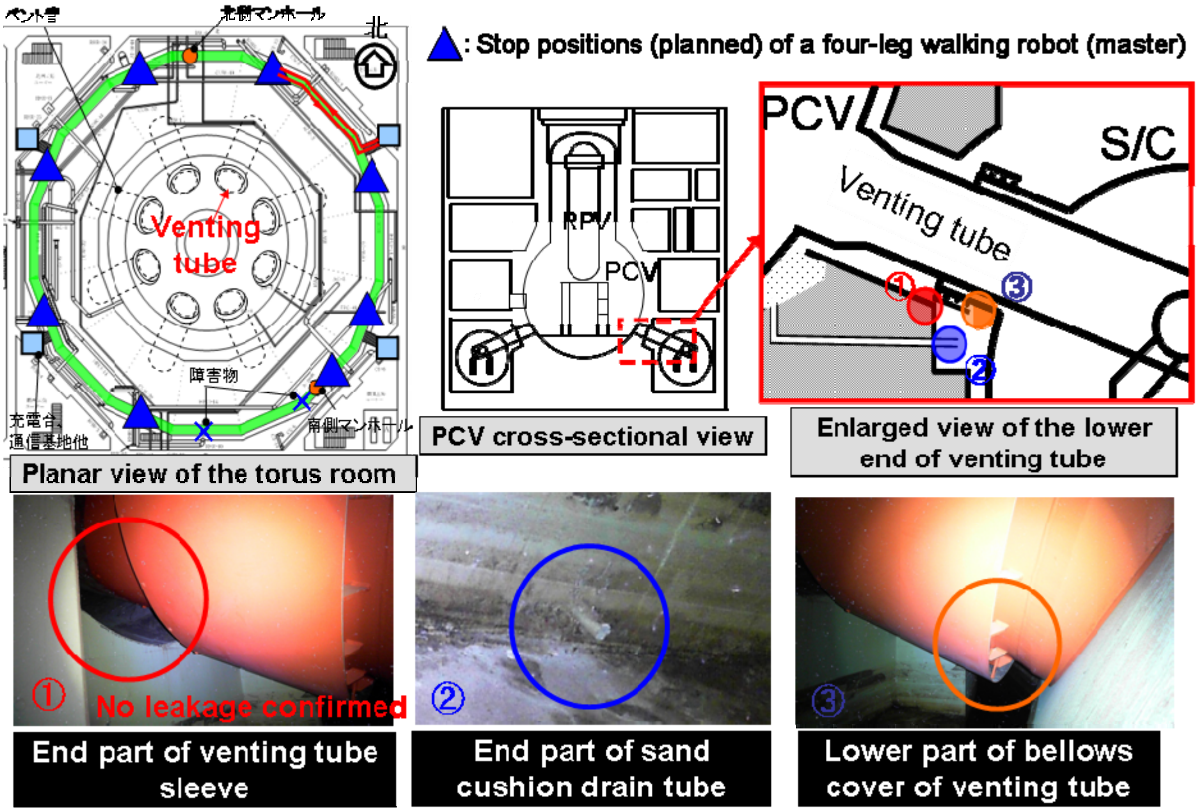


Figure 3-4 Camera photos around the lower end of the venting tube in the torus room of Unit-2 (part)

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*8).

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).

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*7) Progress in preparations for decommissioning of Units-1 to 4 of the Fukushima Daiichi Nuclear Power Plant, March 28th, 2013

*8) Progress in preparations for decommissioning of Units-1 to 4 of the Fukushima Daiichi Nuclear Power Plant, May 7th, 2013

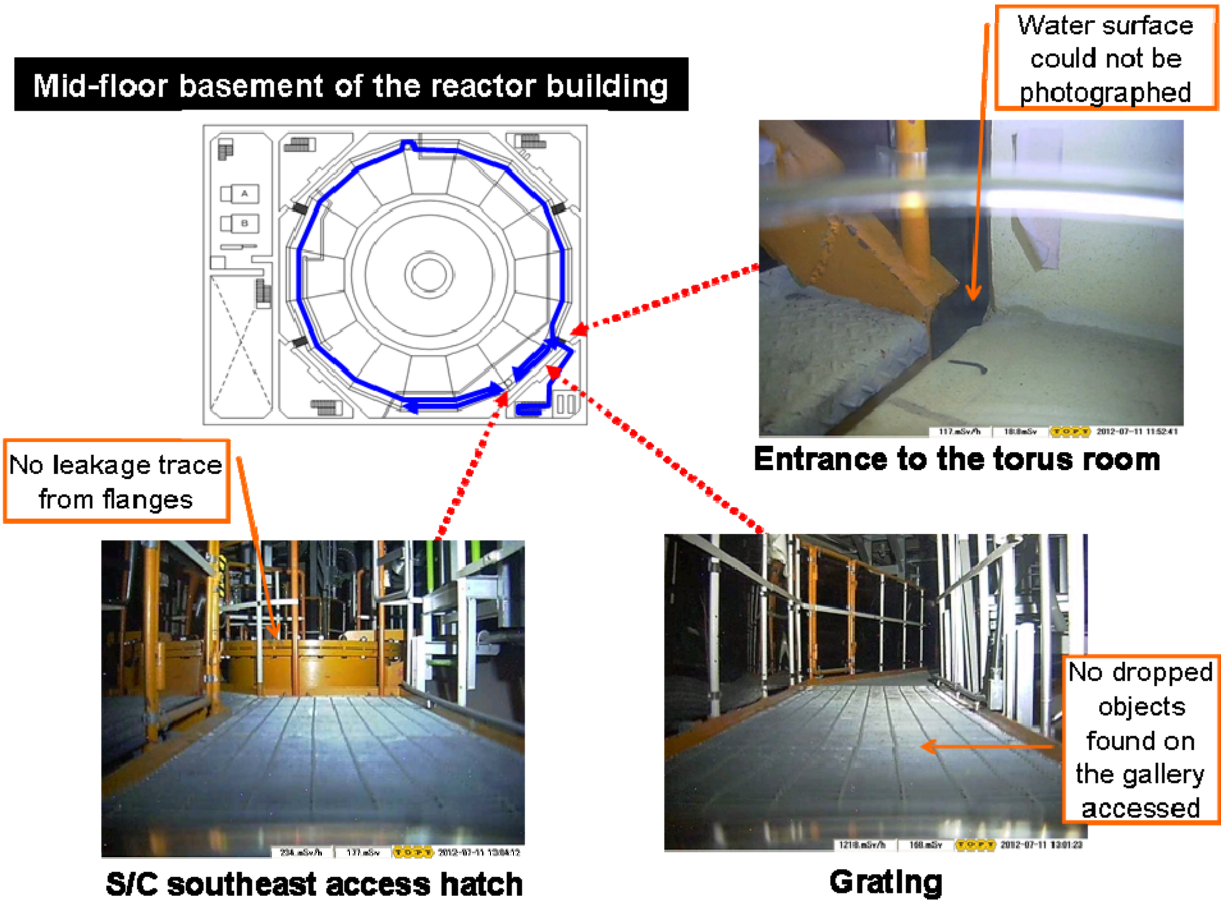

Figure 4-1 Camera photos in the torus room of Unit-3 (part)

(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*9), analyzed again in March and April of 2013). Containment pressures of Unit-1 and Unit-2 PCVs are at 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.

*9) 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 23rd, 2012