Attachment 2-11

FP release behavior at Unit-2 estimated from CAMS readings on March 14th and 15th

1. Outline of the incident and the issue to be examined

At Unit-2 of the Fukushima Daiichi NPS, the reactor water level was just below the top of active fuel (TAF) at the time of reactor depressrization, differing from the water levels of Unit-1 and Unit-3, and the core damage is considered not to have occurred before the reactor depressurization. Upon reactor depressurization, a large amount of cooling water was lost due to flashing and the reactor water level decreased rapidly to as low as below the bottom of active fuel (BAF). At the time of depressurization, fuel is considered to have been cooled by the steam generated by flashing and from this background it is estimated that the core damage occurred at Unit-2 when the reactor pressure was in the lowered situation, the water level was below BAF and then fuel was overheated leading to core damage and core melt.

However, the whole amount of water discharged from fire engines was not injected into the reactor and some of the water discharged is likely to have leaked to bypass paths, as seen in Attachment 1-4. An issue remained for when and in what scale the fuel overheating and zirconium-water reactions had occurred and caused core damage and core melt.

Attachments 2-9 and 2-10 to the Progress Report 3 published in May 2015 presented the examination results for identifying the timing of core damage and core melt. In particular Attachment 2-9 presented an estimation that the core damage and core melt had occurred three times at pressure increases after reactor depressurization as shown in Figure 1 and that the most violent energy release had occurred at the second time of the reactor pressure increase.

Attachment 2-10 estimated the initiation timing of core damage and core melt, and the integrity of the reactor pressure vessel (RPV) and primary containment vessel (PCV), based on the changes of readings with time by the containment atmospheric monitoring system (CAMS) in the drywell (D/W) and suppression chamber (S/C) that are shown in Figure 2. But quantitative relations have not yet been evaluated between the CAMS readings at each transition occasion and the amount of fission products (FPs) released. The change trend hints that the dose increase over the night of March 14th came from the FP transfer from the S/C to D/W, but some items are left that are difficult to explain: the CAMS readings in the upstream S/C were lower than in the downstream D/W (contamination in the S/C looks to be less than in the D/W); there were no FPs which correspond to the attenuation of CAMS readings in the S/C (half-life of about 6 hours) from dawn to early in the morning of March 15th, etc.

In this connection, the FP release behavior in the PCV during the core damage and core melt would be estimated by knowing the correlation between the CAMS readings and the amount of FPs released at each transition occurrence. This document presents the results of the investigation for quantitative explanation of CAMS readings and the FP release behavior during the core damage and core melt by comparing the CAMS readings with the results of simulation analysis of radiation source vs. radiation dose using the ORIGEN and MCNP codes.

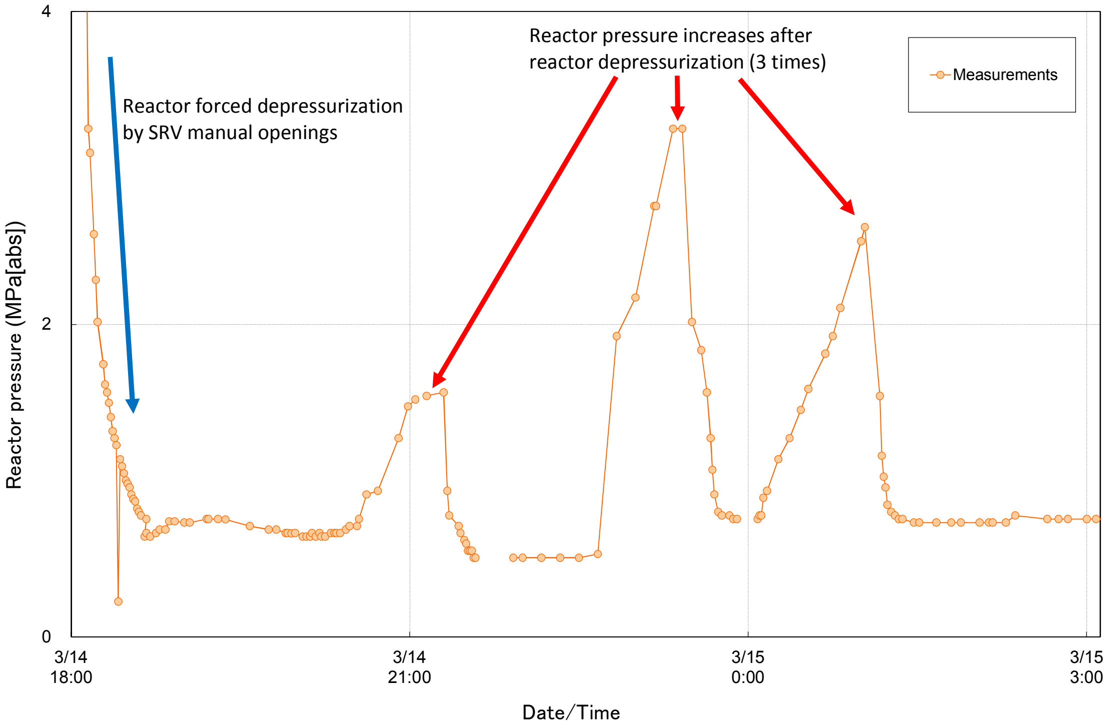

Figure 1 Three reactor pressure increases after reactor depressurization

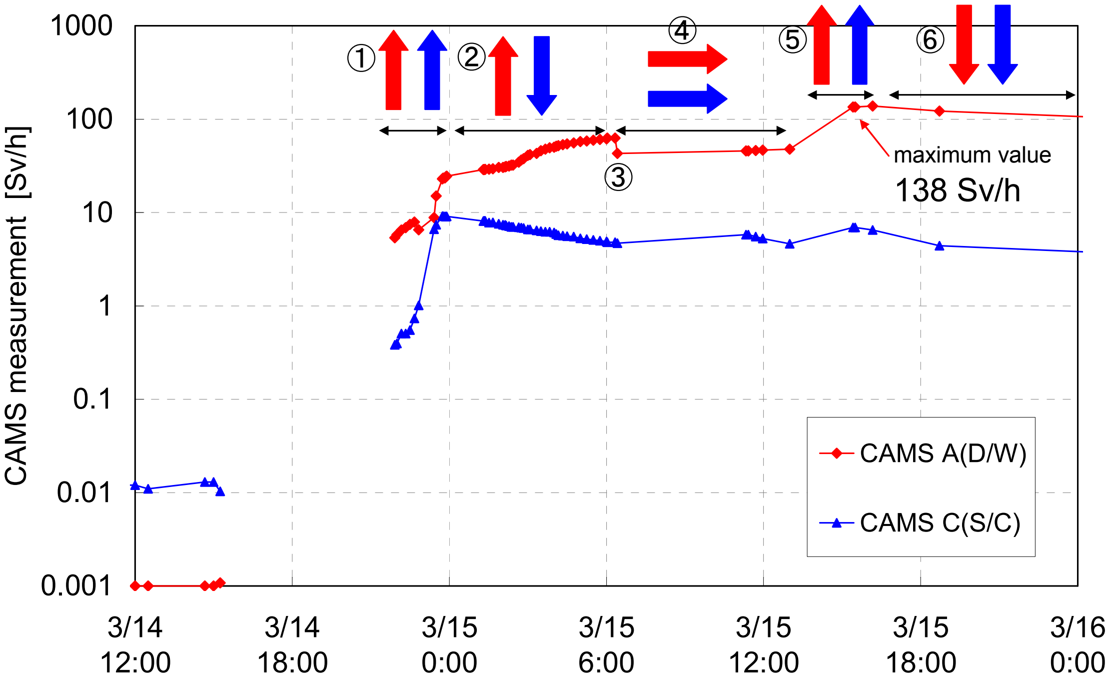

Figure 2 CAMS readings

2. The periods of interest of CAMS readings and behavior

2.1. From 12:00 to 18:00 on March 14th

CAMS readings in the D/W and S/C were low from about 12:00 on March 14th, when a temporary AC power source was connected and the CAMS started to measure the dose rate, to 15:15 on the day, indicating that the fuel integrity had been maintained. The CAMS measurement was interrupted thereafter for a while.

2.2. From 21:55 on March 14th to 00:00 on March 15th (Period ① in Figure 2)

The CAMS measurement restarted at 21:55 and both the dose rates measured in the D/W and S/C increased monotonically over this period. A sharp increase was recognized after about 23:30 and its gradient in the D/W was larger than in the S/C.

2.3. From 00:00 to 06:00 on March 15th (Period ②)

After midnight, the dose rate in the D/W continued to increase, while the dose rate in the S/C tended to decrease.

2.4. From 06:00 to 13:00 on March 15th (Periods ③④)

The dose rate in the D/W decreased sharply in the short time from 06:20 to 06:25, dropping from 62.7Sv/h to 3.0Sv/h.

No big changes were seen thereafter in both the D/W and S/C.

2.5. From 13:00 to 16:10 on March 15th (Period ⑤)

The dose rate measurement in the D/W was halted from 13:00, when 47.7Sv/h was recorded. At 15:25, when the measurement was restarted, the dose rate jumped immediately to 135Sv/h and it reached 138Sv/h (its highest value) at 16:10. Therefore, it is not known exactly when this sharp increase of dose rate occurred, but at least it was a sharp increase in a short time of 3 hours.

2.6. From 16:10 on March 15th to 00:00 on March 16th (Period ⑥)

After the highest dose rate was recorded at 16:10, the dose rate readings decreased monotonically.

3. Location of CAMS detectors

Figure 3 shows approximate locations of CAMS detectors (ion chambers) for the D/W and S/C. The S/C CAMS was located on the wall in the torus room outside the S/C, while the D/W CAMS was located in a PCV penetration. In other words, the S/C CAMS was located apart from where the radiation source was present, while the D/W CAMS was located relatively closer to the radiation source. Consequently, the S/C CAMS is anticipated to give lower readings than the D/W CAMS.

4. Simulated evaluation of CAMS readings

4.1. Analysis conditions

The following conditions were used in the analysis in order to quantitatively evaluate the CAMS readings. But it is impossible to perfectly simulate the D/W and S/C configurations in the analysis. In the current analysis, the S/C was simulated as a cylinder (it is actually a doughnut shape) and the D/W was simulated as a sphere (it is actually a flask shape) combined with a cylinder inside simulating the pedestal. The simulation analysis was intended not for a precise evaluation, but for the quantitative evaluation of relative magnitudes.

- FP inventory in the core and radiation source spectrum evaluation code: ORIGEN
- Radiation dose rate evaluation code for the CAMS position: MCNP5
- Nuclides to be evaluated: Relatively high volatility nuclides, namely noble gases (Kr, Xe), I, Cs (including ^{137m}Ba) and Te
- Geometry for analysis: The torus part of the S/C as a cylinder of 20m length, and the spherical portion of the D/W lower part, nuclear reactor shield walls, the pedestal and the penetration housing CAMS (wall thickness in the radial direction, 19mm; wall thickness on the PCV side, 30mm) (Figures 4 to 6)
- S/C water level: Assumed to be the normal level (OP1650)
- Torus room water level: CAMS assumed not to be water covered (OP70)
- PCV volumes: Cited from the application document for the reactor establishment license (Table 1)
- S/C water volume: Cited from the application document for the reactor establishment license (Table 1)
- FP source distribution: A homogenous distribution assumed for each, the D/W gaseous phase, S/C gaseous phase, S/C liquid phase, D/W walls and S/C walls

Table 1 Spatial volumes in the PCV

Spatial volume			Source for the value
D/W gaseous phase	4.24E+03	m^3	Application document for reactor establishment license
S/C gaseous phase	3.16E+03	m^3	Application document for reactor establishment license
Whole PCV	7.40E+03	m^3	Total of D/W and S/C
S/C water volume	2.98E+03	m^3	Application document for reactor establishment license

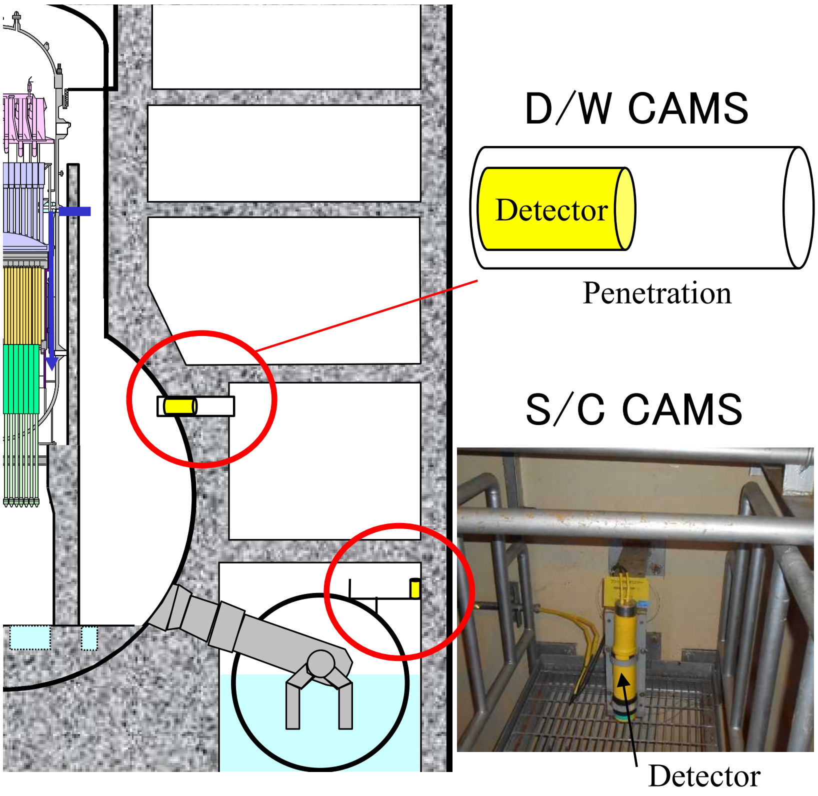

Figure 3 Locations of CAMS detectors in the D/W and S/C

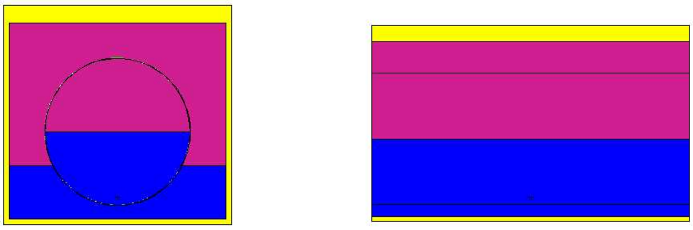

Figure 4 S/C geometry for analysis in the cylinder (left, x-z cross section; right, y-z cross section)

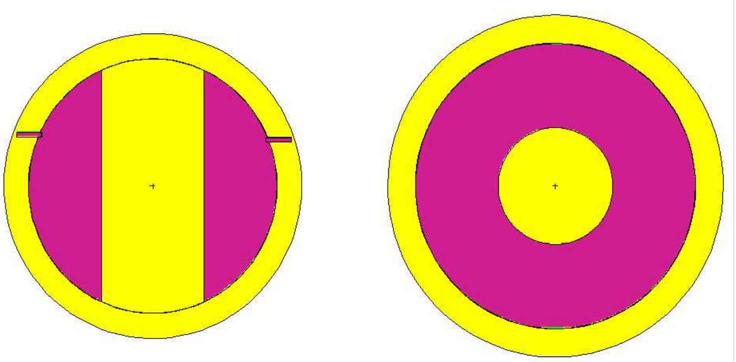

Figure 5 D/W geometry for analysis in the sphere and cylinder (pedestal)

(left, x-z cross section; right, x-y cross section)

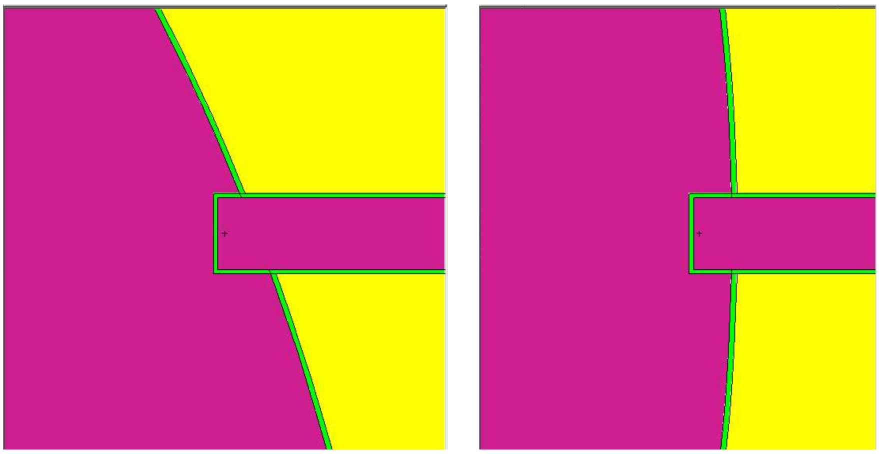

Figure 6 Enlarged D/W geometry for analysis in the penetration
(left, x-z cross section; right, x-y cross section)

Figure 7 shows inventories in the core of the volatile nuclides which are considered dominant contributors to the CAMS readings. As an equivalent value of dose rate, the y-axis is represented as the product of the inventory in the core (Bq) multiplied by the effective energy of photons emitted by the decay of each nuclide. The core damage of Unit-2 started three days or more after the scram, by which time most short-life noble gases had decayed, and iodine was found to have been a major contributor. The half-life of I-132 is only about 2.3 hours, but it remains in radioactive equilibrium with Te-132 (half-life of 3.2 days).

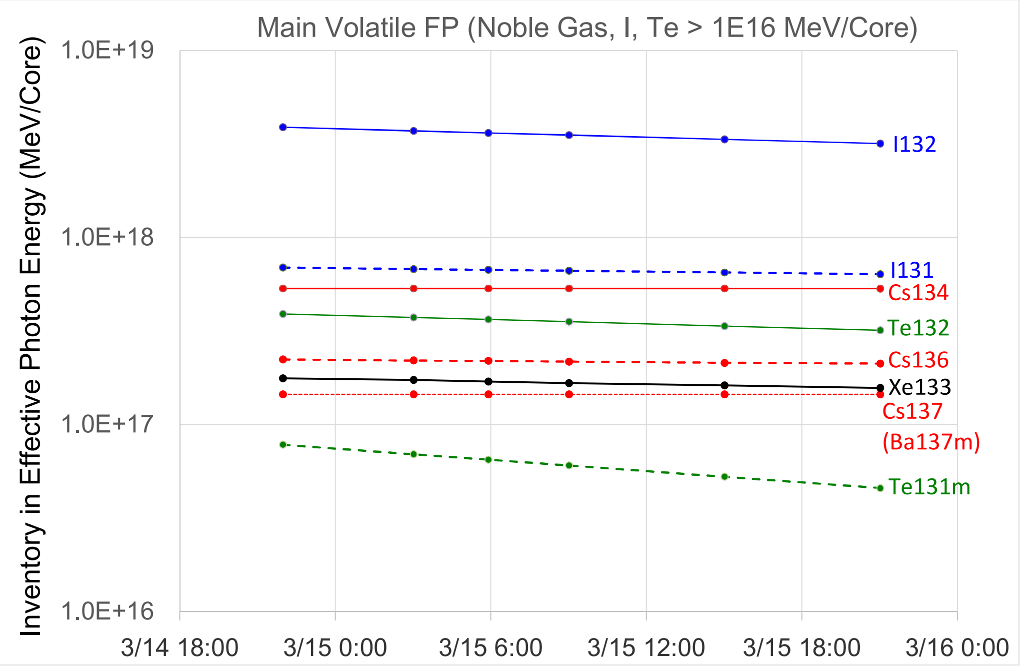

Figure 7 Main volatile FP inventory in the core (in the unit of source energy)

4.2. Analysis results

As a preparatory step, Table 2 shows the CAMS readings anticipated when it was assumed that 100% of the core inventories of each nuclide (noble gas, I, Cs, Te) were released and stayed homogenously in each source position (S/C gaseous phase, S/C liquid phase, S/C inner walls, D/W gaseous phase, D/W inner walls). The amount of the radiation source on the D/W inner walls was calculated by multiplying the whole spherical surface area as the deposition area by the source density, but the value was not very meaningful, because contributions of deposit density distributions, structure surfaces and others were not known.

The actual CAMS readings should be the consequence of contributions of each source element. But the fractions of each element could not be specified. In the analysis of the next chapter, therefore, the release rate of I, Cs and Te from the core was assumed to be 1:1:1.

Table 2 CAMS theoretical readings at each source position

(1) Relations between S/C CAMS readings and sources in the S/C gaseous phase

Date and time	CAMS calculated (each nuclide 100% released) [Sv/h] Release rate needed for measurement (for each element)					CAMS(S/C) measured [Sv/h]
	Noble gas	I	Cs	Te	I+Cs+Te	
3/14 22:00	7.9E-1	6.3E+2	1.2E+2	3.5E+1	7.8E+2	9.1 (3/14 23:42)
	1200%	1.5%	7.7%	26%	1.1%	
3/15 15:00	3.6E-1	5.4E+2	1.2E+2	2.9E+1	6.8E+2	6.9 (3/15 15:25)
	1900%	1.3%	5.9%	24%	1.0%	

(2) Relations between S/C CAMS readings and sources in the S/C liquid phase

Date and time	CAMS calculated (each nuclide 100% released) [Sv/h] Release rate needed for measurement (for each element)					CAMS(S/C) measured [Sv/h]
	Noble gas	I	Cs	Te	I+Cs+Te	
3/14 22:00	—	4.0E+1	7.7E+0	1.7E+0	5.0E+1	9.1 (3/14 23:42)
	—	23%	120%	520%	18%	
3/15 15:00	—	3.5E+1	7.6E+0	1.4E+0	4.4E+1	6.9 (3/15 15:25)
	—	20%	91%	480%	16%	

(3) Relations between S/C CAMS readings and sources on the S/C inner walls

Date and time	CAMS calculated (each nuclide 100% released) [Sv/h]					CAMS(S/C) measured [Sv/h]
	Release rate needed for measurement (for each element)					
	Noble gas	I	Cs	Te	I+Cs+Te	
3/14 22:00	—	6.3E+2	1.2E+2	3.3E+1	7.8E+2	9.1 (3/14 23:42)
	—	1.5%	7.7%	28%	1.2%	
3/15 15:00	—	5.3E+2	1.2E+2	2.6E+1	6.8E+2	6.9 (3/15 15:25)
	—	1.3%	5.9%	26%	1.0%	

(4) Relations between D/W CAMS readings and sources in the D/W gaseous phase

Date and time	CAMS calculated (each nuclide 100% released) [Sv/h]					CAMS(S/C) measured [Sv/h]
	Release rate needed for measurement (for each element)					
	Noble gas	I	Cs	Te	I+Cs+Te	
3/14 22:00	1.2E+0	1.3E+3	2.5E+2	4.9E+1	1.6E+3	22.5 (3/14 23:42)
	2000%	1.8%	9.0%	46%	1.4%	
3/15 3:00	9.5E-1	1.2E+3	2.3E+2	4.2E+1	1.4E+3	62.6 (3/15 6:02)
	6600%	5.4%	27%	150%	4.3%	
3/15 15:00	4.6E-1	9.4E+2	2.3E+2	4.2E+1	1.2E+3	135 (3/15 15:25)
	29000%	14%	59%	320%	11%	

(5) Relations between D/W CAMS readings and sources on the D/W inner walls (*)

Date and time	CAMS calculated (each nuclide 100% released) [Sv/h]					CAMS(S/C) measured [Sv/h]
	Release rate needed for measurement (for each element)					
	Noble gas	I	Cs	Te	I+Cs+Te	
3/14 22:00	—	9.3E+3	1.7E+3	4.1E+2	1.1E+4	22.5 (3/14 23:42)
	—	0.2%	1.3%	5.5%	0.2%	
3/15 3:00	—	8.9E+3	1.7E+3	3.8E+2	1.1E+4	62.6 (3/15 6:02)
	—	0.7%	3.6%	16%	0.6%	
3/15 15:00	—	7.5E+3	1.7E+3	3.3E+2	9.5E+3	135 (3/15 15:25)
	—	1.8%	8%	41%	1.4%	

(*) Sources were assumed to distribute only on the D/W walls (spherical part) and penetration surfaces

5. Deliberation on behavior of CAMS readings and evaluation of the accident progression

The following findings for each timing and period of interest can be drawn from the measured values and the simulated dose analysis results in Chapter 2 to Chapter 4.

5.1. Initiation and progression of core damage (①)

The CAMS readings at 21:55 on March 14th after the measurement was interrupted showed an increase from the level when the core had been integral, indicating that the core damage had started by then. Both CAMS readings in the S/C and D/W increased thereafter, and the S/C CAMS readings were lower than the D/W CAMS readings. This is because, as mentioned in Chapter 3, the S/C CAMS detector was located farther from the source than the D/W CAMS detector, and the behavior of the CAMS readings was consistent with the estimation given in Attachment 2-10 that the FPs released from the core transferred to the S/C via the SRVs and further to the D/W through the vacuum breaker valves while the reactor vessel was integral.

It is likely that the FPs released to the S/C gaseous phase (noble gases included) transferred to the D/W via the vacuum breaker valves. But according to the dose rate evaluation, even if 100% of them was released to the S/C gaseous phase, the whole inventory of noble gases could contribute only about 0.79Sv/h to the S/C CAMS readings because all short-life noble gases had decayed by this time. The CAMS readings at 23:42 on March 14th were 22.5Sv/h (D/W) and 9.1Sv/h (S/C), and therefore it is <u>difficult to explain the S/C dose rate only by the contribution of noble gases</u>. Other contributors are considered as high volatility nuclides other than noble gases trapped in the S/C water or deposited on the S/C walls. This supports the evaluation to date that the core damage and core melt progressed over this period ① and volatile FPs were also released.

It is not possible to specify the contribution fractions from sources in the liquid phase and deposited on the walls, but the amount of FPs can be determined which can reproduce the S/C CAMS readings by the use of decontamination factor (DF), an indicator to show the fraction of FPs trapped in the water. For example, when the DF is 100 (the amount trapped in the water is 100 and the amount released into the gaseous phase is 1), the S/C CAMS reading is 9.1Sv/h by assuming 16% of the core inventory of I, Cs and Te was trapped in the water and 0.16% was deposited on the walls (the whole amount released into the gaseous phase was deposited on the walls). This result is consistent with the actual reading. (Strictly speaking, the contribution to the CAMS readings per unit amount of FPs in the water is reduced by the shielding effect of the water and less than that from FPs deposited on the walls, and the amounts of FPs to produce a reading of 9.1Sv/h only by FPs are 18% (FPs in the water) or 1.2% (FPs deposited on the walls).)

On the other hand, if the whole amount of noble gases is present in the D/W gaseous phase, it contributes about 1.2Sv/h to the CAMS reading, while the actual reading of the D/W CAMS was 22.5Sv/h (at 23:42 on March 14th). Again, it is <u>difficult to explain the D/W dose rate only by the contribution of noble gases</u>. Other contributions are considered to have come from the high volatility FPs other than noble gases transferred from the S/C via S/C vacuum breaker valves to the D/W (in the gaseous phase or deposited on the D/W walls). If about 1.4% of the accumulated I, Cs and Te in the core is present in the D/W gaseous phase, its contribution becomes about 22.5Sv/h. An assumption of about 1.4% transfer of core inventories to the D/W means that 100% of the core inventories were released to the S/C when the DF was 100, which is too big when compared with the S/C CAMS readings mentioned above. In other words, <u>other gaseous</u>

FP-containing species like organic iodine are considered to have contributed by being transferred to the D/W gaseous phase from the RPV via the S/C. Meanwhile, the D/W CAMS reading rapidly increased from 8.81Sv/h to 24.5Sv/h between 23:25 and 23:54. It is conceivable, therefore, that direct leaks occurred at this timing from the RPV to D/W, or that this was a contribution from the FPs deposited on the walls. This time period corresponds to the second reactor pressure increase shown in Figure 1, when the core melt is considered to have been in progress in the reactor. At this stage it is highly probable that the transfer of I, Cs and Te to the D/W was limited and most still remained in the RPV. (The CAMS is located in the D/W penetration and receives big influences from the deposited FPs on the wall. If FPs were assumed to have deposited with uniform surface densities on the inner wall of the D/W sphere, 0.2% of I, Cs and Te inventories in the core can reproduce the D/W CAMS readings when deposited on the wall.)

5.2. Progression of FP direct release from RPV to D/W (②)

The characteristic feature of this period is the decreasing trend of S/C dose rate, which hints at the direct release from the RPV to the D/W, not from the RPV to the S/C as occurred till then. The CAMS readings were 24.5Sv/h (D/W) and 9.10Sv/h (S/C) at 23:54 on March 14th and 62.7Sv/h (D/W) and 4.80Sv/h (S/C) at 06:20 on March 15th. The S/C dose rate halved in about 6 hours. There is no single nuclide among the FPs which has the half-life of about 6 hours. In the case of high volatility FPs such as I, Cs and Te being released from the fuel, the collective dose rate would have decreased depending on the amounts of the individual FPs released. If a combination of released amounts is found which apparently halves in about 6 hours, the behavior of S/C CAMS readings during the period ② can be explained.

Figure 8 shows the energy changes (proportional to dose rate) with time emitted from I, Cs and Te. Each element alone is assumed to exist at time 0 and the energy emitted thereafter includes the energy emitted from its daughter nuclides. The iodine energy halves in about 2 hours at the beginning, being dominated by ^{132}I (half-life of about 2.3 hours). But ^{132}I is a daughter nuclide of ^{132}Te (half-life of about 3.2 days), and attenuates in the half-life of ^{132}Te in the core, because ^{132}I exists in radioactive equilibrium with ^{132}Te. In Figure 8, the energy of ^{132}I born from ^{132}Te is counted as the energy from ^{132}Te, and therefore the energy emitted from Te increases at the beginning by the ^{132}I, being born. For similar reasons, the energy from Cs slightly increases due to ^{137m}Ba being born.

Consequently, if Te in the FPs released to the S/C is a relatively low fraction, the attenuation of ^{132}I becomes dominating and the collective dose rate attenuates faster. Particularly, if the abundance ratio of I to Te is assumed to be 1 to 0.2, the collective dose rate halves in 6 hours. It is reasonable that less Te exists than I because of their different volatilities. The S/C CAMS readings would have changed according to such a difference in the abundance ratio of I and Te.

The D/W CAMS readings reached as high as 62.7Sv/h at 06:20 on March 15th. Even if the whole amount of noble gases was assumed to exist in the D/W gaseous phase, as assumed in time period ①, the contribution to the D/W CAMS readings is limited to about 0.95Sv/h. If about 4% of the I, Cs and Te in the core was released to the D/W gaseous phase, it would account for about 60Sv/h (if only I was released, about 5% of it would account for about 60Sv/h). This means that, although the D/W CAMS readings showed a fairly big increase in the morning of 15th, the amount of direct release to the D/W from the RPV was not as big as the amount of radioactive materials released to the D/W via the S/C on the night of 14th. Concerning the contribution of radioactive materials deposited on the D/W walls, an assumption of 0.6% of I, Cs and Te in the core being deposited on the inner surface of the D/W sphere can reproduce the D/W CAMS readings. As a result, it can be concluded to be highly likely that the transfer of I, Cs and Te to the D/W was limited during this period ② as in ① and most of them remained in the RPV or they were present where it was difficult for their radiation emissions to reach the CAMS detectors, such as in the pedestal or on the D/W floor.

5.3. D/W dose rate decrease (③)

From 06:20 to 06:25 on March 15th the D/W dose rate dropped sharply from 62.7Sv/h to 43.0Sv/h, while the S/C dose rate leveled off. This rapid decrease of dose rate (CAMS readings) could have come from measurement errors, but a scenario was explored that radioactive materials in the D/W had been released with the steam release from the R/B blow-out panel of Unit-2 (Figure 9), which had been recognized. In this scenario, 100% of the noble gases were released on this occasion, but their contribution was only 0.73Sv/h, insufficient to explain this sharp drop. If 43.0Sv/h was assumed to come only from I, Cs and Te in the gaseous phase, about 3.1% of the core inventory in the D/W gaseous phase was enough to reproduce the dose rate, indicating that about 1.2% of the core inventory was released to the atmosphere from the D/W. But this evaluation result seems to have big uncertainties because of (i) the unlikelihood of this big amount of release in this short period, (ii) no CAMS readings being available till 11:25, five hours after, and (iii) inconsistency of the dose rate drop timing with the D/W decrease timing.

5.4. Dose rate stable (④)

Over this period, both D/W and S/C CAMS readings were stable, although the measurement points were limited. On the other hand, the D/W pressure changed violently and gaseous leaks from the D/W were considered to have been progressing. If the dose rate from the gaseous phase were dominant, the CAMS readings should have decreased according to the leaks. Since that was not the case, the S/C CAMS readings are likely to have measured the radiation from the FPs trapped in the water or deposited on the S/C walls, while the D/W CAMS readings are likely to have measured the radiation from the FPs deposited on the D/W walls.

5.5. Dose increase to the highest level (⑤)

The D/W CAMS readings indicated a sharp dose increase from 13:00 to 15:25 on March 15th. To reproduce the value at 16:10 of 138Sv/h, about 11% of the core inventories of I, Cs and Te are necessary in the D/W gaseous phase, i.e., an additional 8% of the core inventories might have been released to the D/W. This amount is bigger than the amount during ② when continuous leaks were assumed from the RPV to the D/W. If this big amount of FP transfer occurred from the RPV to the D/W in this limited time of ⑤, it could be explained as due to RPV damage during this time period.

Simultaneously, the S/C CAMS readings were also increasing. That could have been caused by the FP transfer from the D/W to the S/C via vent tubes due to the PCV violent pressure change as a result of the RPV damage.

But, as mentioned later, the dose rate decreased monotonically thereafter for a long time. The D/W CAMS readings are likely to have measured the radiation from the FPs deposited on the D/W walls. In this case, the amount of FPs released to the D/W from the RPV becomes less than about 8% assumed in the current evaluation. Since the direct release from the D/W to the R/B and further to the environment started during this time period, some FPs might have taken leak paths which did not affect the CAMS readings (leaks through a leak path from the RPV flange to the top head part of the D/W is an example). It is not easy to specify the amount of release during this period ⑤.

By this time, about 20 hours had passed since the core damage and core melt had started, and therefore, it is considered that most of the volatile FPs had been released from the fuel. Further examination is needed to specify the FP transfer mechanism which can explain the sharp increase of D/W CAMS readings to their highest value at the timing of RPV damage. It can be concluded from the examination to date that the amounts of I, Cs and Te transferred to the D/W were limited and most of them remained in the RPV or they were present where it was difficult for their radiation emissions to reach the CAMS detectors, such as in the pedestal, on the D/W floors or in the top head part of D/W, and part of them was released to the R/B basement floors after being transferred to the liquid phase.

5.6. Attenuation over a long term (⑥)

After the highest readings were recorded at 16:10 on March 15th, the CAMS readings decreased monotonically. Around March 19th, CAMS readings were decreasing with roughly a half-life of about 8 hours (Figure 10). Although the D/W pressure changed, the CAMS readings continued to decrease monotonically over a long term. It is considered that this was because the CAMS measured mainly the radiation from FPs (I, Cs) deposited on the D/W walls.

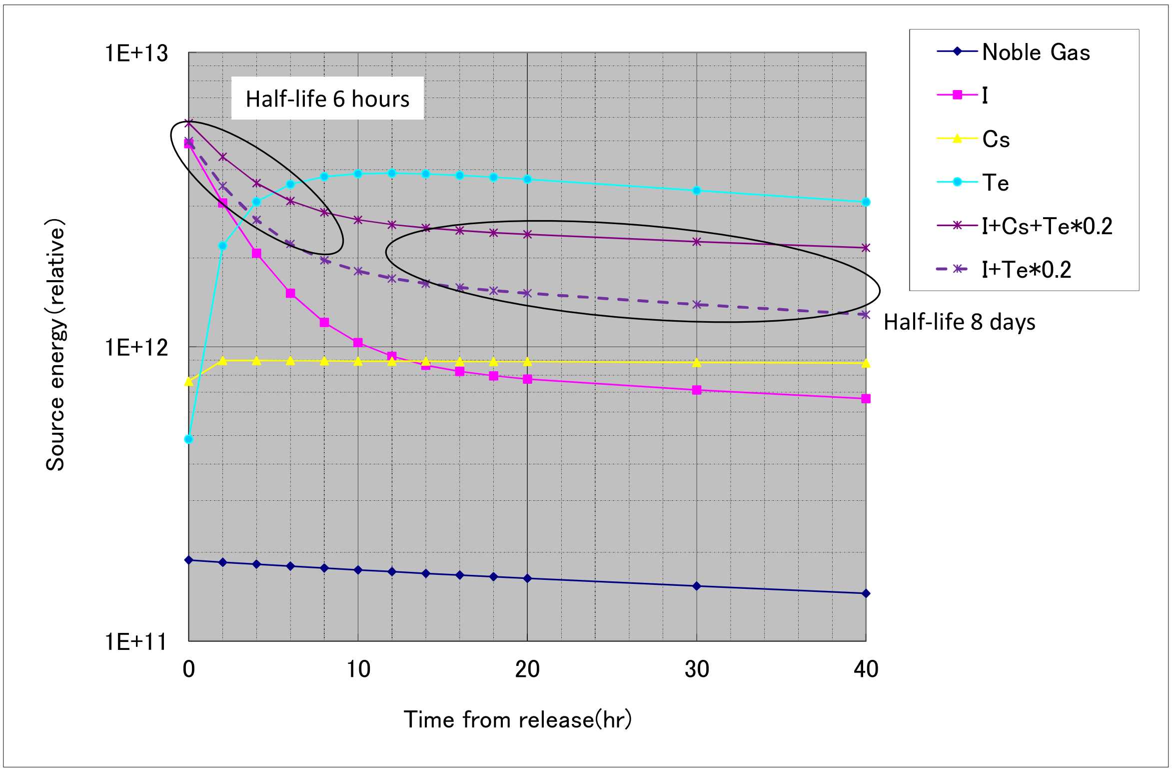

Figure 8 Time change of source energy of each element

Figure 9 Steam release from Unit-2 (taken at 08:58 on March 15th)

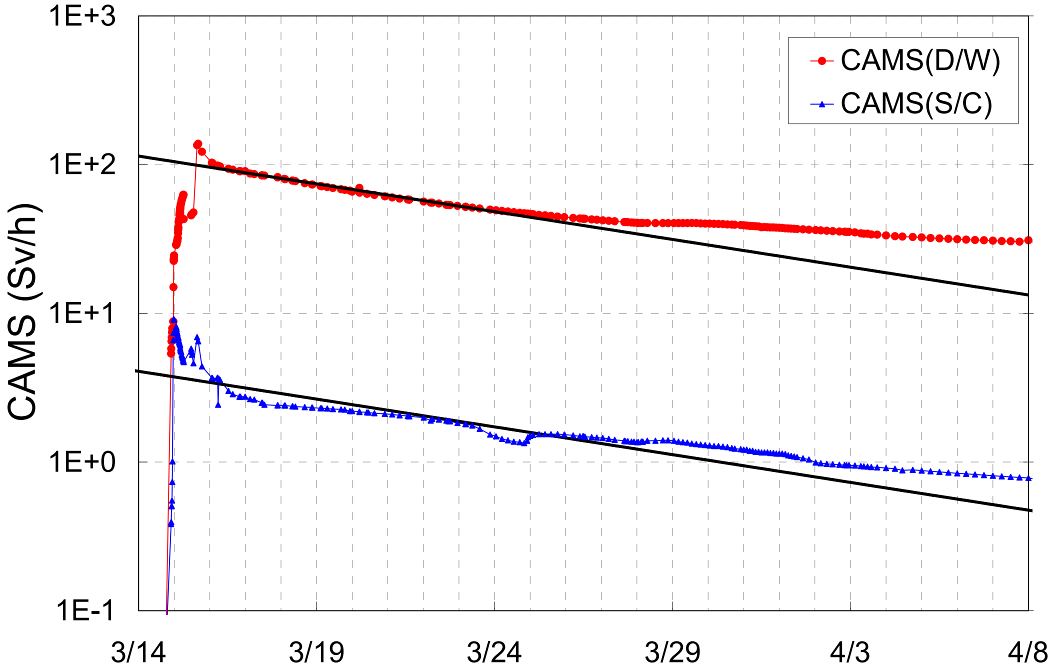

Figure 10 Long-term changes of CAMS readings
(the linear line shows the attenuation in a half-life of 8 days)

6. Summary of deliberations on CAMS readings at the D/W and S/C

The CAMS readings obtained at Unit-2 were quantitatively examined, and the accident progression scenario deducted therefrom was examined, in continuation from the examination in Attachment 2-10. Key conclusions are the following.

- The accident progression scenario presented in Attachment 2-10 is consistent with the quantitative evaluation of dose rate changes.
- Core damage progressed during ①, and not only noble gases but also volatile FPs such as iodine and cesium are estimated to have been released from the fuel (CAMS readings cannot be explained by the release of noble gases only).
- Most FPs (I, Cs, Te) released from the fuel stayed in the RPV, and gaseous or aerosol FPs transferred to the S/C water via the SRVs during ①. The amount of FPs transferred to the S/C water could be estimated as about 16%, based on the S/C CAMS readings (this is just a reference value, because the abundance ratio between FPs trapped in the S/C liquid phase and deposited on the walls is unknown). Part of the FPs transferred from the S/C gaseous phase to the D/W via vacuum breaker valves (1 to 2%, probably a contribution from organic iodine species).
- The RPV was likely to have been integral in period ①. Only after 23:30 on March 14th, might direct leaks to the D/W have occurred, since the D/W CAMS readings showed a sharp increase.
- Over the period ②, direct leaks from the RPV to D/W continued, but the amount of FPs

transferred to the D/W was limited, and most FPs stayed in the RPV. Part of the FPs, which transferred to the D/W, deposited on the D/W walls or on other surfaces.

- During the periods ③ and ④, gaseous leaks occurred from the D/W to the environment and FPs in the D/W gaseous phase were released to the environment. But no big changes were seen in the D/W CAMS readings because of the contribution from the FPs deposited on the walls. If there were no contribution to the D/W CAMS readings from the deposited FPs, the amount of FPs in the D/W gaseous phase had been about 3% at most, which is only slightly inconsistent with the evaluation ("Estimation of Radioactive Material Release to the Atmosphere during the Fukushima Daiichi NPS Accident", May 2012, TEPCO) that a few percent of the FPs were released to the environment.
- The sharp increase of CAMS readings during the period ⑤ is likely to be connected to the RPV damage. A larger amount of FPs than before is considered to have been transferred at this timing to the D/W and to have caused the highest CAMS readings. But the relation between the RPV damage and the FP transfer mechanism remains unknown. The long-term attenuation trend of the CAMS readings thereafter over the period ⑥ indicates a possibility that FPs deposited on the D/W walls contributed to the CAMS readings.

7. The issue examined and its relationship with safety measures

This examination was intended to reveal the PCV pressure decrease mechanism. As such, there is no direct relationship to safety measures. But, as was seen in this examination, the CAMS readings are a very important source of information for estimating the accident progression behavior. Therefore, it is important to strengthen the power supply systems in order to secure CAMS integrity at the time of an accident. It is also necessary, when core melt occurs, to take the FPs other than noble gases or deposited FPs into account in interpreting the CAMS readings.

The existing version of severe accident management procedures specifies that the core damage fraction is to be evaluated based on the CAMS readings with an assumption of only noble gases present. The current examination has shown, however, that it is difficult for this assumption to lead to meaningful values. An examination is being undertaken into the concepts used to interpret the evaluation of core damage fraction.